FUEL CONSUMPTION AND EXHAUST EMISSIONS FROM A HEAVY-DUTY HYBRID BUS

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The introduction of prototype heavy-duty hybrid vehicles introduces a number of challenges in assessing emissions performance compared to conventionally powered diesel or gasoline-fueled, heavy-duty vehicles. Difficulty is encountered because the engine may be operated on an intermittent basis (as a function of load or state of charge of the energy storage system) and in a narrow speed/load range. An engine test alone would not characterize the hybrid vehicle's emissions or fuel economy. Therefore, in this project, heavy-duty chassis dynamometer emission measurements were used to benchmark the fuel consumption and exhaust emissions of a heavy-duty hybrid vehicle against a conventionally powered vehicle. The hybrid bus was powered with a CNG-fueled, VW 2.0L engine. Exhaust emissions from the hybrid bus were compared to a 1996 model year diesel-powered bus operated over the same driving cycles, and using the same inertia weight and road load as the hybrid bus. SwRI noted that the aftermarket CNG fuel system installed on the 2.0L VW engine did not function adequately; therefore, the exhaust emissions from the hybrid bus lcould have been much better if detailed optimization had been performed. In fact, NOx emissions were 25 to 30 percent higher than for the diesel bus. However, even with the non-optimum CNG fuel system, the exhaust emissions of NMHC and CO were significantly lower than observed for a comparable diesel bus. Although not directly measured, PM emissions from the hybrid bus were assumed to be essentially zero. Another significant finding was that the fuel consumption of the hybrid bus was 13 to 30 percent better than the diesel bus over the CBD-14 cycle, and 38 to 45 percent better than the diesel bus over the HDCC.

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EXECUTIVE SUMMARY

The introduction of prototype heavy-duty hybrid vehicles introduces a number of challenges in assessing emissions performance compared to conventionally powered diesel or gasoline-fueled, heavy-duty vehicles. Difficulty is encountered because the engine may be operated on an intermittent basis (as a function of load or state of charge of the energy storage system) and in a narrow speed/load range. An engine test alone would not characterize the hybrid vehicle's emissions or fuel economy. Therefore, in this project, heavy-duty chassis dynamometer emission measurements were used to benchmark the fuel consumption and exhaust emissions of a heavy-duty hybrid vehicle against a conventionally powered vehicle. The hybrid bus was powered with a CNG-fueled, VW 2.0L engine. Exhaust emissions from the hybrid bus were compared to a 1996 model year diesel-powered bus operated over the same driving cycles, and using the same inertia weight and road load as the hybrid bus. SwRI noted that the aftermarket CNG fuel system installed on the 2.0L VW engine did not function adequately; therefore, the exhaust emissions from the hybrid bus could have been much better if detailed optimization had been performed. In fact, NOx emissions were 25 to 30 percent higher than for the diesel bus. However, even with the non-optimum CNG fuel system, the exhaust emissions of NMHC and CO were significantly lower than observed for a comparable diesel bus. Although not directly measured, PM emissions from the hybrid bus were assumed to be essentially zero. Another significant finding was that the fuel consumption of the hybrid bus was 13 to 30 percent better than the diesel bus over the CBD-14 cycle, and 38 to 45 percent better than the diesel bus over the HDCC.

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This work was made possible by the Allison Transmission Division of General Motors and the Defense Advanced Research Projects Agency (DARPA). The hybrid test vehicle was provided and supported by Allison and project funding was via contract with DARPA. Pat Wildemann was the primary contact at Allison while John Gully and Bob Rosenfeld were the program managers at DARPA.

Project Manager for emissions tests at SwRI was Steven G. Fritz, Senior Research Engineer in the Department of Emissions Research. The SwRI technical monitors were Mr. Edward A. Bass, Manager of Advanced Vehicle Technology, Mr. Terry L. Ullman, Manager of Heavy-Duty Technology Assessment, and Mr. Charles T. Hare, Director, Department of Emissions Research. Mr. Ed Grinstead and Mr. Glenn Boehle performed technical support for the project.

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LIST OF ABBREVIATIONS

APU	auxiliary power unit
AVS	Advanced Vehicle Systems, Incorporated
bhp	brake horsepower
BTU	British Thermal Units
CARB	California Air Resources Board
CBD	Central Business District
CCR	California Code of Regulations
CFR	Code of Federal Regulations
CH_4	methane
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CVS	constant volume sampling
EPA	Environmental Protection Agency
°F	degrees Fahrenheit
g	grams
GVWR	gross vehicle weight rating
HC	hydrocarbons
HDCC	heavy-duty chassis cycle
HFID	heated flame ionization detector
hp	horsepower
hr	hour
L	liter
lb	pound
mi	mile
NDIR	non-dispersive infrared
NMHC	non-methane hydrocarbons
NO_x	oxides of nitrogen
PM	particulate
psi	pounds per square inch
regen	regenerative energy
rpm	revolutions per minute
scf	standard cubic feet
SOC	state of charge of battery
SwRI	Southwest Research Institute
THC	total hydrocarbons
VIN	vehicle identification number

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1. 0 INTRODUCTION

Heavy-duty vehicles are designed for a variety of purposes and use a variety of engines, transmissions, and rear-end drive arrangements. Because of these variations, the Environmental Protection Agency (EPA) regulates emissions from heavy-duty engines instead of heavy-duty vehicles. The EPA defines heavy-duty vehicles as vehicles with a gross vehicle weight rating (GVWR) over 8,500 pounds (1).[1]

The introduction of prototype heavy-duty hybrid vehicles introduces a number of challenges in assessing emissions performance compared to conventionally-powered diesel or gasoline fueled heavy-duty vehicles. For this program, heavy-duty chassis dynamometer emission measurements were used to benchmark the fuel economy and exhaust emissions of a heavy-duty hybrid vehicle against a conventionally powered vehicle.

Emissions measured included "total" hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), carbon dioxide (CO_2), and methane (CH_4). The difference between total hydrocarbons and methane are non-methane hydrocarbons (NMHC). Particulate emissions were only measured on the baseline diesel vehicle.

2. 0 EXPERIMENTAL APPROACH

2.1 Test Vehicles

For baseline diesel testing, a 1996 Carpenter 3800 series school bus (VIN No. 1HVBBABN8SH269489) was obtained from the North East Independent School District of San Antonio, Texas. The school bus, shown in Figure 1, was rated for a GVWR of 29,000 pounds, and was powered with a Navistar 7.3 liter V-8 T444E diesel engine rated at 190 bhp at 2,300 rpm. The bus was equipped with an Allison AT-500 4-speed automatic transmission. The school bus had accumulated 19,856 miles before baseline testing.

[1]Underscored numbers in parentheses refer to the list of references at the end of this report.

Figure 2 shows the hybrid shuttle bus manufactured by Advanced Vehicle Systems (AVS) in Chattanooga, Tennessee (VIN No. 1A9BT14S3RC309009). The hybrid bus was manufactured in June 1994, and has a GVWR of 17,000 pounds. The hybrid auxiliary power unit (APU) was a VW 2.0 liter spark-ignited engine fueled by compressed natural gas (CNG) using an IMPCO ADP closed-loop fuel system. The APU was equipped with a Nelson catalytic muffler as part of the exhaust system.

Although the physical size of the school bus was notably different than the hybrid shuttle bus, the power train in the school bus was similar to that used in diesel-powered shuttle buses. The preferred comparison of the hybrid drive system to a conventional diesel power train would have involved obtaining a diesel-powered AVS shuttle bus. Unfortunately, such a vehicle does not exist since the hybrid AVS was a prototype, purpose-built vehicle designed to demonstrate hybrid electric technologies. Therefore, baseline testing of the school bus was performed at the same inertia weight and road load horsepower used for testing the hybrid bus. This approach will provide a reasonable, "apples to apples" comparison.

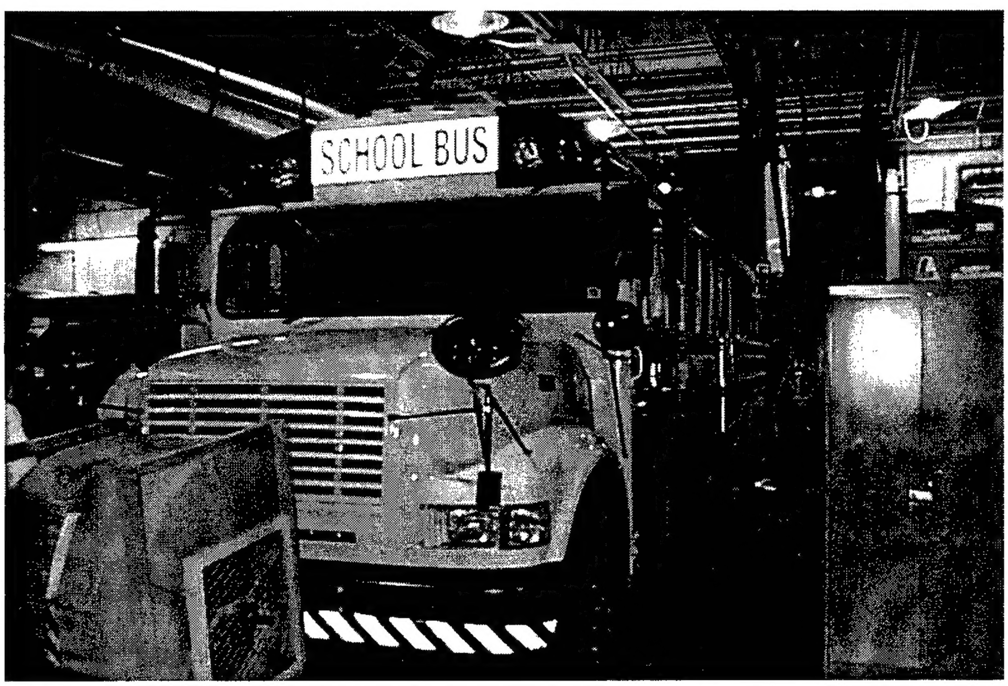

Figure 1. <u>1996 Carpenter School Bus Used for Baseline Diesel Testing</u>

Figure 2. Allison Hybrid Bus Installed on Heavy-Duty Chassis Dynamometer

2.2 Test Fuels

Baseline tests on the diesel school bus were performed using a diesel fuel meeting EPA fuel specifications for emissions certification of heavy-duty diesel engines (2). Pertinent specifications for the test fuel, referred to as SwRI test fuel EM-2445-F, are given in Table 1.

Emission testing of the hybrid bus was performed using natural gas fuel meeting the California Air Resources Board (CARB) emission test specifications outlined in §1956.8 of Title 13 of the California Code of Regulations (CCR), but containing no oxygen pursuant to CARB Manufacturer's Advisory Correspondence (MAC) 93-05. The CARB natural gas fuel specification and the analyses of the actual test fuel are given in Table 2. This specification also meets EPA requirements for emission-grade natural gas fuel as specified in §86.1213- 94(d) of Title 40 of the U.S. Code of Federal Regulations (CFR). Natural gas test fuel was blended to CARB specifications by SwRI and

stored in a pressure vessel mounted on a trailer that holds approximately 5,800 scf of natural gas at a pressure of 3,000 psig. Gas was supplied to the filling valve on the bus with the on-board tanks isolated to operate the APU on gas supplied from the external tank.

Table 1. Properties of Diesel Fuel Used for Baseline School Bus Testing

Determinations	ASTM Test Method	Test Fuel	EPA On-Hwy. Type 2-D Fuel Spec.[a]
API Gravity @ 60°F	D4052	35.8	32 - 37
Viscosity @ 40°C (cSt)	D445	2.57	2.0 - 3.2
Sulfur (Wt%)	D2622	0.034	0.03 - 0.05
Cetane Index	D976	47.7	40-48
Cetane Index	D4737	48.4	
Cetane Number	D613	45.8	40 - 48
Hydrocarbon Type	D1319		
Aromatics (%)		30.0	>27
Olefins (%)		1.7	
Saturates (%)		68.3	
SFC Aromatics (vol. %)	D-5186	28.48	
Specific Gravity		0.8563	Report
Flash Point (°F)	D93	166	>130
Distillation	D86		
	% Recovered	Temp. °F	
	IBP	374	340 - 400
	5	414	
	10	437	400 - 460
	20	455	
	30	472	
	40	489	
	50	504	470 - 540
	60	519	
	70	535	
	80	555	
	90	584	560 - 630
	95	608	
	FBP	631	610 - 690
SwRI Fuel Code		EM-2445-F	

Note: a - 40 CFR §86.1313-94(b)(2) Type 2-D Diesel Fuel Specification

Table 2. CARB Specifications of Natural Gas (CNG) for Emission Testing			
Property	**CARB Specification**	**Hybrid Bus Test Fuel**	**Test Method**
Hydrocarbons (expressed as mole percent)			
Methane	90.0% ± 1%	90.3	ASTM D 1945-81
Ethane	4.0% ± 0.5%	3.8	ASTM D 1945-81
C_3 and higher HC	2.0% ± 0.3%	2.1	ASTM D 1945-81
C_6 and higher	0.2% (max.)	0.0	ASTM D 1945-81
Other Species (expressed as mole percent unless otherwise indicated)			
Hydrogen	0.1 % (max.)	0.0	ASTM D 2650-88
Carbon monoxide	0.1% (max.)	0.0	ASTM D 2650-88
Oxygen[a]	0.5% ± 0.1%	0.0	ASTM D 1945-81
Inert Gases			
Sum of CO_2 and N_2	3.5% ± 0.5%	3.8	ASTM D 1945-81
Water	b		
Particulate	c		
Odorant	d		
Sulfur	16 ppm by vol. (max.)		Title 17 CCR Section 94112

[a] Oxygen content of fuel-gas is allowed to be less than 0.5 mole % provided other components comply with respective specifications per CARB Manufacturers Advisory Correspondence 93-05.
[b] The dew point at vehicle fuel storage container pressure shall be at least 10°F below the 99.0% winter design temperature listed in Chapter 24, Table 1, Climatic Conditions for the United States, in the American Society of Heating, Refrigerating and Air Conditioning Engineer's (ASHRAE) Handbook, 1989 fundamentals volume. Testing for water vapor shall be in accordance with ASTM D 1142-90, utilizing the Bureau of Mines apparatus.
[c] The compressed natural gas shall not contain dust, sand, dirt, gums, oils, and other substances in an amount sufficient to be injurious to the fueling station equipment or the vehicle being fueled.
[d] The natural gas at ambient conditions must have a distinctive odor potent enough for its presence to be detected down to a concentration in air of not over 1/5 (one fifth) of the lower limit of flammability.

2.3 Heavy-Duty Chassis Dynamometer

Chassis tests were performed in accordance with procedures outlined in an EPA report titled "Recommended Practice for Determining Exhaust Emissions from Heavy-Duty Vehicles Under Transient Conditions" (3). The simulated inertia weight used for both the school bus and the hybrid bus was 14,600 pounds, which was determined using the empty weight of the hybrid bus (approximately 13,000 pounds) plus an estimated 10 passengers weighing 150 pounds each. The road load was computed based on the frontal area of the hybrid bus and the inertia test weight as specified in the EPA-recommended procedure. The resulting total theoretical road load at 50 mph

was 52 horsepower (hp). For the hybrid bus, this theoretical road load was calculated by considering rolling resistance of 17 hp and aerodynamic influences of 35 hp as outlined in the EPA procedure. A road load of 52 hp at 50 mph was also used for baseline school bus testing.

Each heavy-duty vehicle required its own sampling system configuration, chassis dynamometer tie down adjustment, and set-up. Figures 1 and 2 show the vehicles set-up on the heavy-duty chassis dynamometer.

For this test program, baseline school bus emissions were measured over cold-start and hot-start runs using two different driving cycles. One cycle, the EPA Urban Dynamometer Driving Schedule (UDDS) For Heavy-Duty Vehicles, is illustrated in Figure 3. This driving cycle is also known as the heavy-duty chassis cycle (HDCC). The HDCC is 1,060 seconds long and covers a distance of 5.55 miles (8.94 km). The official use of this cycle is for preconditioning heavy-duty gasoline-fueled vehicles before an evaporative emissions test. However, the HDCC is commonly used for exhaust emissions testing of heavy-duty vehicles, and is generally considered to approximate the engine speed and load conditions found in the EPA heavy-duty diesel engine certification test procedure.

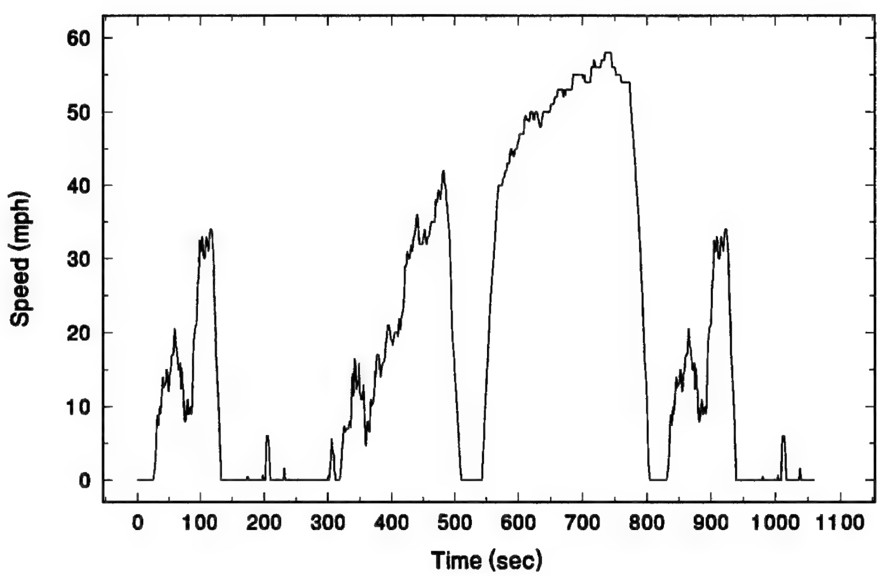

Figure 3. Urban EPA Dynamometer Driving Schedule for Heavy-Duty Vehicles

The second test cycle used for this program is known as the Central Business District (CBD) cycle. The CBD cycle is one of four transit coach operating profile duty cycles adopted by the Federal Transit Administration (FTA) of the U.S. Department of Transportation. For this project, the "CBD-14" cycle was comprised of 14 repetitions of the basic cycle shown in Figure 4, which includes idle, acceleration to 20 mph (32.2 kph), cruise, a sharp deceleration to a stop, then a repeat of the basic cycle starting with idle. The CBD-14 cycle used in this work, shown in Figure 5, was 580 seconds in length and covered a distance of 2.0 miles (3.2 km).

For baseline school bus tests, cold-start and hot-start emission tests were run using both driving cycles. Hot-start emission tests were run in replicate because they are generally considered more important in determining weighted composite emissions, reflecting the fact that most engines are typically cold-started only once per day. For the school bus, the order of test was cold-start CBD-14, 20 minute engine off soak, hot-start CBD-14, 20 minute soak, then a hot-start HDCC. The following day started with a cold-start HDCC, then a 20 minute soak, a hot-start HDCC, 20 minute soak, and finally a hot-start CBD-14. Preparatory runs were completed at least 12 hours prior to cold-start emission testing.

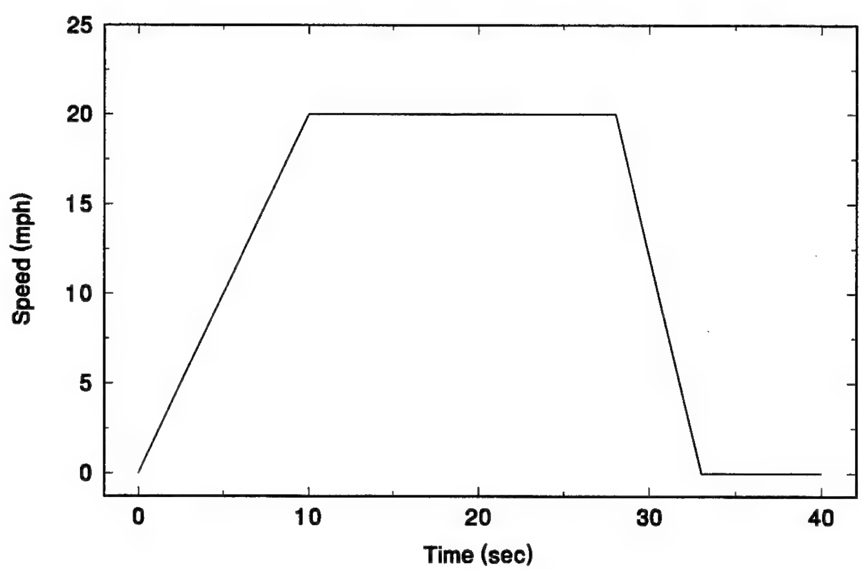

Figure 4. Single Segment of the CBD Driving Cycle

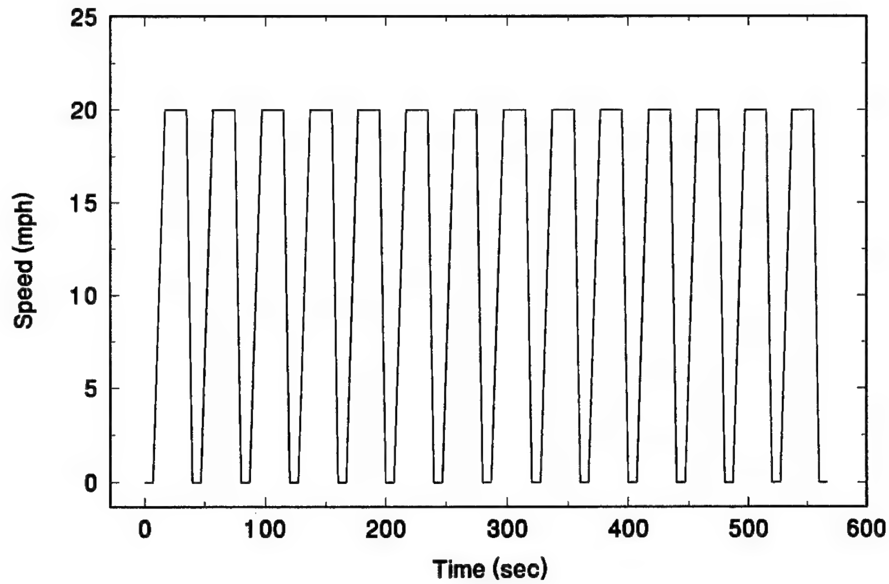

Figure 5. CBD-14 Cycle

In preparation for the cold- and hot-start record tests, the school bus was operated at 50 mph, and the road load on the dynamometer was set to 52 hp. One CBD practice cycle was run followed by a recheck of the dynamometer load at 50 mph. The bus was then shut down for an overnight soak at ambient temperature (68-86°F). The EPA Recommended Procedure specifies that the vehicle remain inoperative for at least 12 hours before the cold-start test. Following the overnight soak, the bus was tested over the test sequence described earlier.

The hybrid bus operated in a pure electric mode until the state of charge (SOC) dropped below a defined level, then the APU began to operate. Therefore, the test sequence used for the hybrid bus was notably different than that used for the school bus. Testing of the hybrid bus was performed using the same driving cycles, inertia weight, road load, and preparatory sequence used for the school bus. However, the test sequence was modified to establish a reproducible characterization of the hybrid bus emissions and fuel economy. For this program, all emissions testing of the hybrid bus started with the on-board battery pack charged to 100-percent SOC.

For CBD-14 cycle testing, the hybrid bus was operated over nine consecutive CBD-14 driving cycles. The selection of nine CBD-14 cycles was determined during testing and was based on observations of the SOC during repetitive CBD cycles. Using the APU operating characteristics set by the vehicle manufacturer (Allison), the APU started during the fourth CBD-14 cycle. Therefore, there were no cold-start emissions during initial bus operation and through the first three CBD-14 cycles. Cold-start emissions from the APU were measured as part of the fourth CBD-14 cycle. Thereafter, five additional CBD-14 cycles were run with the APU operating.

A similar approach was used for the hybrid bus operating over the HDCC. Because the HDCC is a longer test with higher vehicle speeds and associated loading, the APU started during the second HDCC. An additional four HDCC tests were performed with the APU running, for a total of six consecutive HDCC cycles used to test the hybrid bus.

Steady-state emissions of the hybrid bus APU were measured at 5, 10, 15, 20, and 25 kW of APU output. These tests were run with the bus in "park," using the on-board computer to fix the APU output to the desired level. Before these steady-state APU tests were run, the SOC of the on-board battery packs was run down to approximately 40 percent so that the APU power output would be used to charge the batteries during emissions testing.

2.4 Analytical Procedures

The analytical procedures used to measure and calculate the exhaust emissions produced and the fuel consumed during the tests are given in the EPA report for heavy-duty chassis testing (3), and those given in the Federal Register for heavy-duty gasoline and diesel engine testing (2), and incorporated procedures adopted by CARB for testing CNG-fueled, heavy-duty engines (4,5).

Following diesel engine testing protocols for the baseline school bus, total hydrocarbon and NO_x concentrations were continuously monitored in the dilute exhaust over each test, and the integrated result was used in computing emissions. NO_x correction factors for engine intake air humidity were applied as is specified in the transient FTP for diesel-fueled engines (2,5).

CARB procedures for spark-ignited, CNG-fueled engines were used for hybrid APU testing. Therefore, HC and NO_x emissions were measured using proportional dilute exhaust bag samples. In addition to total hydrocarbons, a gas chromatograph determined methane content of the proportional dilute exhaust bag samples using SAE Method J1151 (6). Non-methane hydrocarbons (NMHC) are essentially "total hydrocarbons" (HC) minus "methane." These calculations take into account procedures recommended by CARB for computing NMHC (7). NO_x correction factors for engine intake air humidity were applied as specified in the transient FTP for gasoline fueled engines (2,4).

For both the school bus and the hybrid bus, concentrations of CO and CO_2 in the proportional dilute exhaust bag samples were determined by non-dispersive infrared (NDIR) instruments (2). Particulate emissions were measured only on the baseline diesel school bus, using dilute sampling techniques as is specified in the transient FTP for diesel-fueled engines (2,5).

Emission levels for THC, CO, CO_2, and NO_x were processed along with CVS flow parameters and vehicle operating parameters to compute mass emissions on the basis of distance (g/mi). These computations were based on the equations specified in the Federal Register (2) for exhaust emissions from gasoline engine exhaust, and take into account modifications necessary for using CNG fuel as outlined in the California Code of Regulations governing certification standards of new heavy-duty vehicles fueled with natural gas (4).

It is important to note that these tests were not conducted to a federal test procedure, which for heavy-duty applications is an engine test procedure. For additional discussion on heavy-duty hybrid vehicle testing, refer to SAE paper No. 952611.

3. 0 BASELINE DIESEL TEST RESULTS

Average composite exhaust emissions from the 1996 Carpenter school bus are summarized in Table 3. Following EPA procedures, composite emissions were computed by weighting the cold-start emissions by 1/7 and the hot-start emissions by 6/7. Individual data sheets from each test are given in Appendix A.

Table 3. Baseline Diesel School Bus Results						
Composite Cycle [a]	HC (g/mi)	CO (g/mi)	NO_x (g/mi)	PM (g/mi)	Fuel Economy (mpg)	(BTU/mi)
CBD-14	1.3	3.8	15.2	0.25	8.1	16,200
HDCC	0.8	2.3	12.4	0.24	8.5	15,300
Note: a - Composite based on 1/7 x average cold-start + 6/7 x average hot-start emissions.						

The measured fuel economy was compared to fuel economy records kept by the North East Independent School District for this model and year bus. Their records show an average fuel economy of 7.8 mpg, with a sample standard deviation of 0.39 from 23 buses. Therefore, the measured fuel economy results seem reasonable.

4.0 HYBRID BUS TEST RESULTS

Initial testing of the hybrid bus revealed that the NO_x and CO levels from the APU were unexpectedly high. Raw exhaust analysis of the APU using a Horiba air fuel ratio (a/f) analyzer revealed that the APU was running very rich of stoichiometric. Diagnostic testing performed by SwRI confirmed that the engine was running rich, and that the IMPCO ADP fuel system was not running closed-loop (i.e., modulating the a/f ratio around stoichiometric).

SwRI requested and received a copy of the ADP service manual via fax from Onan. Onan packaged the APU for Allison. Following the service manual instructions, SwRI adjusted the CNG fuel system carburetor and pressure regulator while observing the ADP O_2 sensor output and the Horiba a/f until closed-loop operation was achieved. The ADP system functioned properly above 17 kW, but below this load, closed-loop control was lost. However, the a/f stayed close to stoichiometric. Below 17 kW, carburetor or pressure regulator adjustments did not bring the ADP into a closed-loop mode. Note that the default APU load table on the bus calls for a lot of 10 - 15 kW APU output. Therefore, it is important for the ADP to operate in a closed-loop mode in this range. SwRI also sought assistance from IMPCO.

In addition to the fuel system running rich, SwRI suspects that the Nelson "catalytic muffler" was not very efficient in reducing NO_x emissions. When running rich, with no O_2 in the exhaust, the NO_x should have been low, but was not. In fact, when SwRI leaned out the engine to closed-loop operation, the raw NOx concentration downstream of the catalyst was on the order of 2,500 ppm, which would be expected for a straight engine out level. SwRI proposed to remove the Nelson muffler and temporarily replace it with a three-way automotive catalyst that had demonstrated ULEV emissions on CNG. Allison agreed to this proposal.

During the fuel system diagnostic activity, SwRI discovered an exhaust leak between the exhaust manifold and the exhaust-pipe flange. The presence of an exhaust leak voids the early hybrid bus APU emission measurements, because a leak results in artificially low emission and fuel consumption results (i.e., our high results would be even higher). While removing the Nelson muffler and installing the 3-way catalyst, SwRI confirmed the exhaust leak was between the exhaust manifold and the exhaust-system flange. The gasket was disintegrated, and SwRI replaced it with one made in-house.

After the ADP fuel system was adjusted, the exhaust leak repaired, and the new catalyst was installed, SwRI performed the emission tests on the hybrid bus. Exhaust emission and fuel economy test results from the hybrid bus operating over the CBD-14 cycle are given in Table 4. Individual test data sheets for each CBD-14 test are given in Appendix B. Exhaust emissions and fuel economy measured over nine consecutive CBD-14 test cycles, starting with the batteries at 100-percent SOC, are provided. Recall that each CBD-14 test cycle is 580 seconds long and covers a distance of two miles. Therefore, Table 4 represents continuous operation of the bus for 5,220 seconds (1 hour and 27 minutes), covering a distance of 18 miles.

Table 4 shows that the APU started during the fourth CBD-14 cycle, and remained on during subsequent test cycles. The results from cycle numbers 5 through 9 indicate that the APU system reached a pseudo-equilibrium operating condition for this test cycle, and the emissions and fuel economy essentially stabilized.

Table 4. CBD-14 Cycle Hybrid Bus Results						
CBD-14 Cycle Number	THC (g/mi)	NMHC (g/mi)	CO (g/mi)	NO_x (g/mi)	PM (g/mi)	Fuel Economy (BTU/mi)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	1.6	0.30	0.17	11.4	***	7,700
5	1.3	0.29	0.13	19.4	***	12,100
6	1.4	0.34	0.05	20.3	***	11,800
7	1.4	0.36	0.09	21.7	***	12,000
8	1.3	0.34	0.13	20.0	***	11,600
9	1.3	0.32	0.13	19.7	***	11,900
Note: a - PM not measured during hybrid bus testing. Assumed to be essentially 0 g/mi for CNG engines.						

Table 5 provides the emissions and fuel economy results for the hybrid bus operating over six consecutive HDCC tests. Individual test data sheets for each HDCC test are given in Appendix C. Recall that each HDCC is 1,060 seconds long and covers a distance of 5.55 miles. Therefore, Table 5 represents continuous operation of the bus for 6,360 seconds (1 hour and 46 minutes), covering a distance of 33.3 miles.

Table 5 shows that the APU started during the second HDCC, and it remained on during subsequent test cycles. The results from cycle numbers 2 through 6 indicate that the APU system reached a pseudo-equilibrium operating condition for this test cycle, and the emissions essentially stabilized.

Table 6 provides the results of steady-state APU tests performed at several load points. APU load was fixed by operating the bus with the APU disabled to discharge the on-board batteries to a relatively low SOC (approximately 40 percent). The APU was then engaged and the output load fixed via a laptop computer supplied by Allison. A series of seven-minute tests was performed at each of the six load points selected. Individual test data sheets for each steady-state APU test are provided in Appendix D.

Table 5. HDCC Hybrid Bus Results						
HDCC Test Number	THC (g/mi)	NMHC (g/mi)	CO (g/mi)	NO_x (g/mi)	PM (g/mi)	Fuel Economy (BTU/mi)
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.52	0.11	0.09	4.9	***	3,300
3	0.88	0.17	0.12	16.2	***	8,400
4	0.82	0.09	0.17	16.2	***	8,300
5	0.72	0.08	0.20	15.7	***	8,600
6	0.68	0.10	0.20	15.6	***	8,600
Note: a - PM not measured during hybrid bus testing. Assumed to be essentially 0 g/mi for CNG engines.						

Table 6. Hybrid Bus Steady-State APU Test Results					
Measured APU Output (kW)	THC (g/hr)	NMHC (g/hr)	CO (g/hr)	NO_x (g/hr)	Fuel Economy (BTU/hr)
4.0	13.3	0.36	85.7	0.6	72,900
7.5	18.6	1.87	101.9	0.6	93,500
11.0	23.4	1.46	59.5	19.2	116,000
14.0	5.6	0.96	0.6	194.2	141,000
17.5	4.4	1.96	1.7	309.8	189,000
23.0	35.9	22.38	2.3	573.4	248,000
Note: a - PM not measured during hybrid bus testing. Assumed to be essentially 0 g/mi for CNG engines.					

Note the dramatic difference between the low load emissions (at 4.0, 7.5, and 11.0 kW) and the high load emissions. Above 11 kW, the CNG fuel system operated in a closed-loop manner, i.e., at an air/fuel ratio close to stoichiometric (approximately 17:1). At 11 kW and below, the fuel control system was unable to operate closed-loop, and a rich air/fuel ratio resulted in high hydrocarbon and carbon monoxide emissions, but relatively low NO_x emissions.

5.0 EMISSIONS AND FUEL ECONOMY COMPARISON OF CONVENTIONAL DIESEL POWER TRAIN TO CNG-FUELED HYBRID

A comparison of the exhaust emission and fuel economy results obtained from the school bus powered by a conventional power train with a diesel engine and the CNG-fueled hybrid bus is presented below. Although the physical size of the school bus was notably different than the hybrid shuttle bus, the power train in the school bus was similar to that used in diesel-powered shuttle buses. The preferred comparison of the hybrid drive system to a conventional diesel power train would have been to obtain a diesel-powered AVS shuttle bus. Unfortunately, such a vehicle does not exist since the hybrid bus was a purpose-built, one-of-a-kind, demonstration vehicle. However, because baseline testing of the school bus was performed at the same inertia weight and road load horsepower used for testing the hybrid bus, there is basis for a reasonable "apples to apples" comparison.

Exhaust emissions of THC, NMHC, CO, NO_x, and PM over repetitive CBD-14 cycles are shown in Figure 6. For the diesel school bus, the first CBD-14 cycle represents an average of the two cold-start tests performed, where the bus was parked for at least twelve hours at an ambient temperature between 68-86°F (20-30°C). The second CBD-14 test cycle is the average of three hot-start CBD-14 tests performed on the school bus (provided in Appendix A). Subsequent hot-start CBD-14 tests shown in Figure 6 are assumed to have the same emission rate as the average hot-start CBD-14.

Figure 6 shows that the hybrid bus was operating on purely electric power for the first three CBD-14 cycles, and that the APU started during the fourth CBD-14 cycle. The APU did not turn on immediately because the hybrid bus batteries at the beginning of the test were at 100-percent SOC. The data in Figure 6 also suggests that the emissions from the hybrid bus quickly established a pseudo-equilibrium rate, which is a function of the APU power output controlled by the on-board computer. Stabilized THC emissions are essentially equal when comparing the emission results of the diesel school bus to the CNG-fueled hybrid bus. Most of the hydrocarbon emissions from the CNG-fueled bus are methane, which is generally considered non-reactive in ozone formation. Therefore, for each test of the hybrid bus, a separate methane measurement was taken so that the

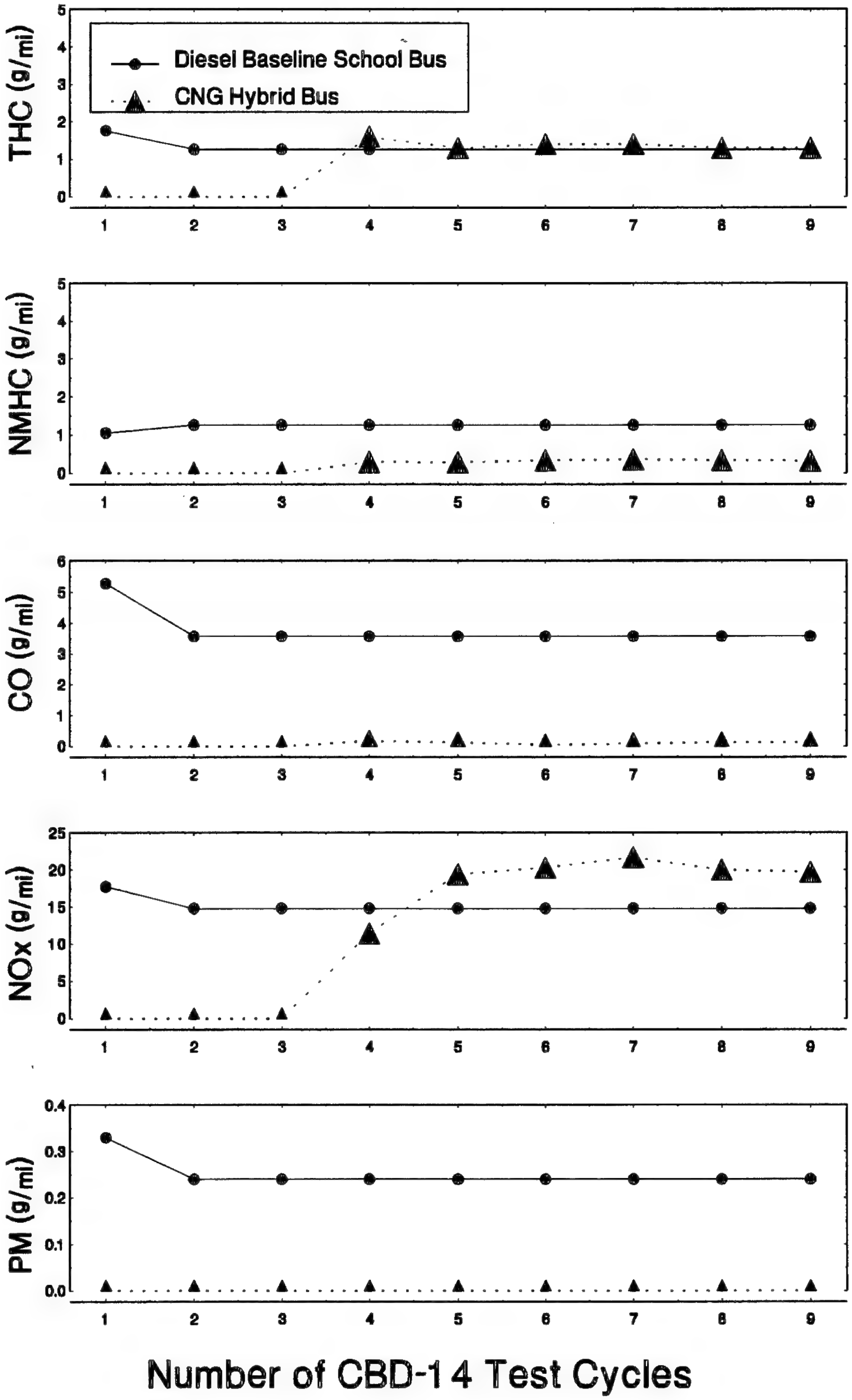

Figure 6. **CBD-14 Emissions Comparison**

non-methane hydrocarbons (NMHC) could be computed. The NMHC results in Figure 6 show that the hybrid bus had considerably lower NMHC emissions than the diesel school bus. CO emissions from the hybrid bus were also dramatically lower. The stabilized NO_x emissions are about 25 to 30 percent higher than the diesel school bus. Although PM emissions from the hybrid bus were not measured, they are assumed to be essentially zero for CNG engines.

Recall that the ADP fuel system was unable to achieve closed-loop operation at loads below roughly 17 kW, and therefore, the CNG fuel system should be considered far from optimized. With a properly functioning closed-loop CNG fuel system, the hybrid bus emissions could be improved considerably over what was observed in these tests.

Figure 7 shows similar results for the HDCC tests. Like the CBD-14 tests, the first HDCC test on the diesel school bus represents an average of two cold-start tests, and the hot-start HDCC tests are an average of triplicate HDCC tests. The HDCC results show similar emission trends to the hybrid bus operating over the CBD-14 cycle: similar THC emissions; much lower NMHC, CO, and PM levels; and slightly higher NO_x levels.

Fuel economy, expressed in BTU per mile, is provided in Figure 8 for the CBD-14 cycle and in Figure 9 for HDCC operation. At first, these results seemed to indicate that the stabilized fuel economy of the hybrid bus was about 25 percent better than the diesel school bus over the CBD-14 cycle, and was about 45 percent better over the HDCC. However, a more detailed analysis of the results, described below, reveals a slightly different scenario.

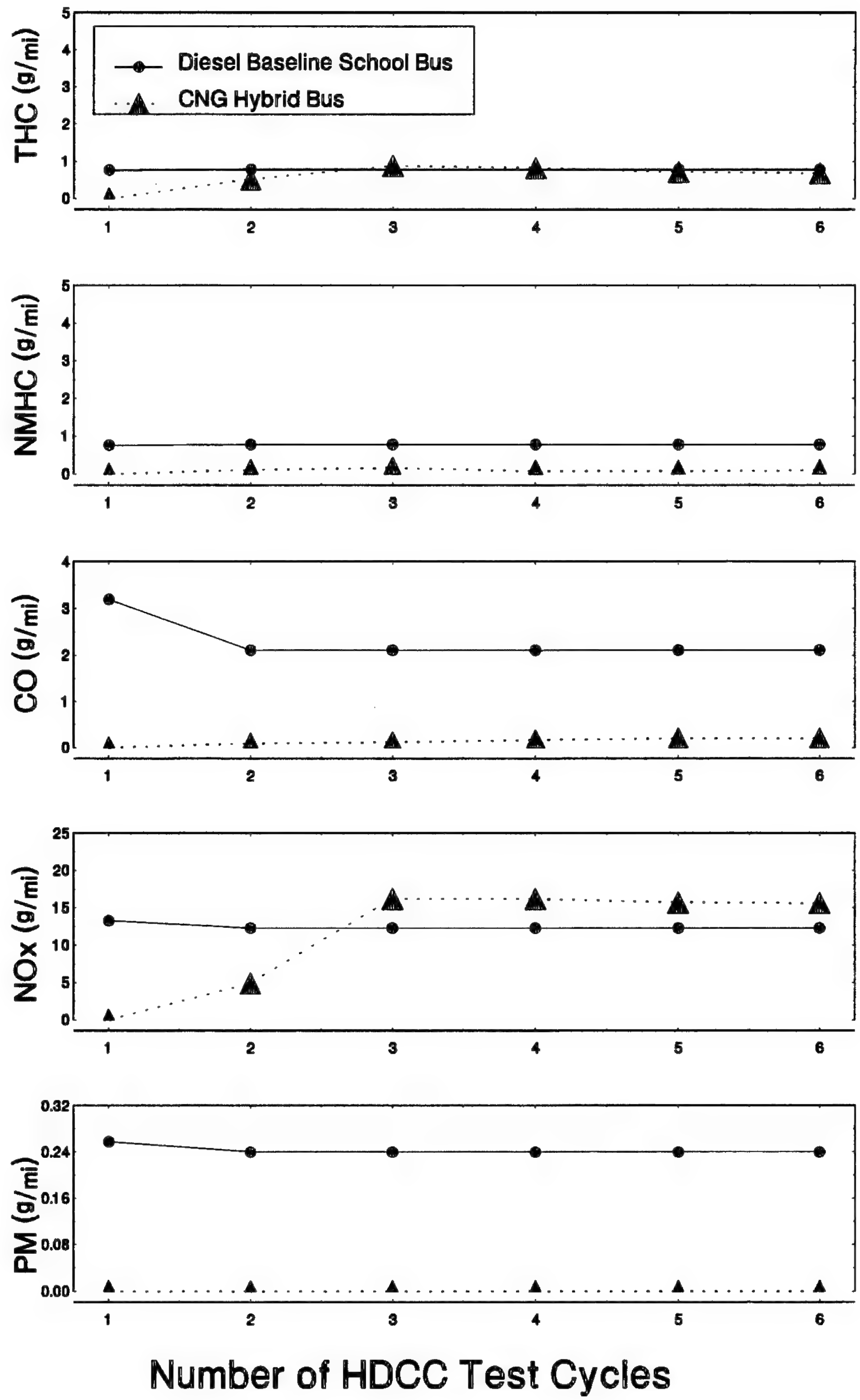

Figure 7. <u>HDCC Emissions Comparison</u>

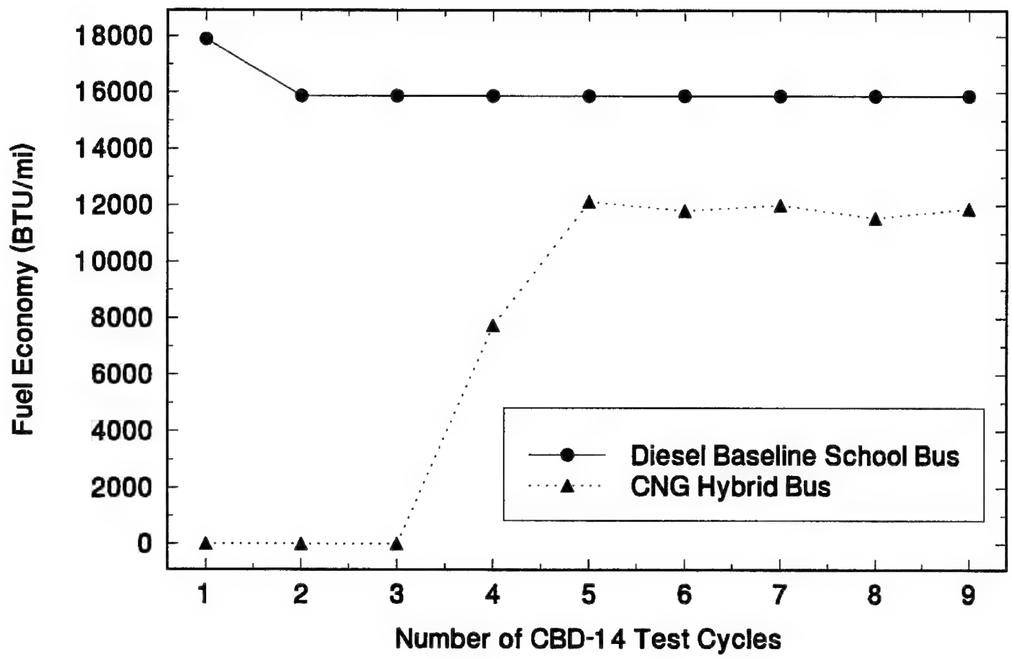

Figure 8. CBD-14 Fuel Economy Comparison

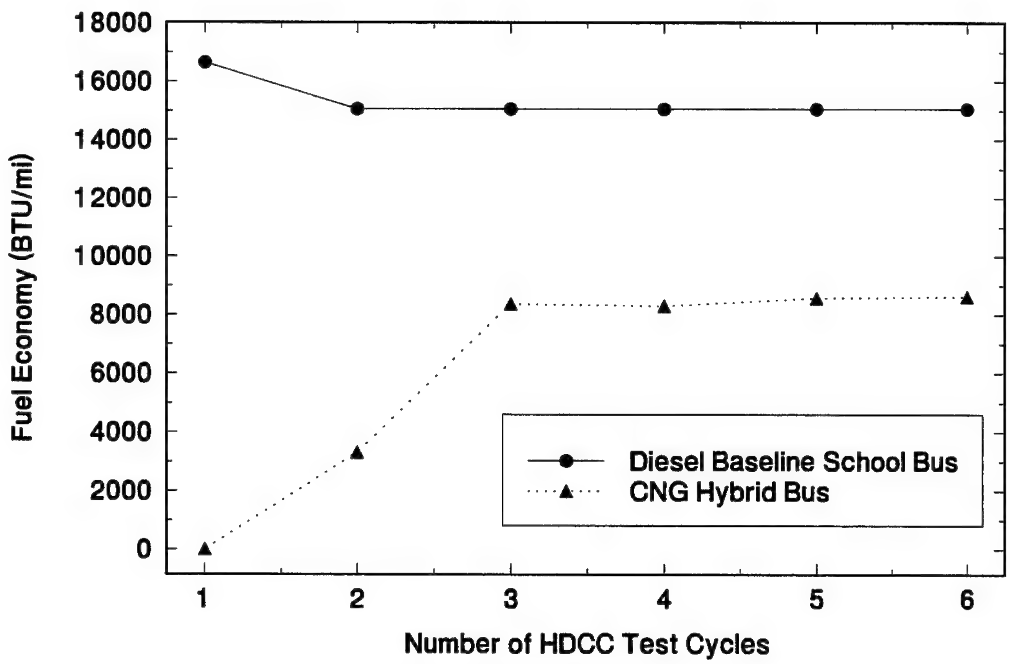

Figure 9. HDCC Fuel Economy Comparison

6. 0 ENERGY CONSUMPTION ANALYSIS AND COMPARISON

The figures above compare actual fuel economy between the conventional diesel-fuel vehicle and the CNG-fuel hybrid vehicles. However, it is well known that fuel consumption on a hybrid vehicle is a function of the battery SOC and changes in SOC.(9) To account for changes in SOC that may have occurred during the tests, a new evaluation procedure was required and was developed especially for this project. The basic philosophy of the procedure was to compare the total energy consumed by each vehicle during the HDCC and the CBD-14 cycles. In the case of the conventional vehicle, calculation of the total energy consumed is very simple since the only source of energy comes directly from the diesel fuel. Knowing the amount of fuel consumed, one can calculate the amount of energy consumed as follows:

$$E_{consumed} = Sum(m_{fuel\ per\ cycle}) * HV_{fuel} * C_1 \qquad (1)$$

where,

m_{fuel} = amount of fuel consumed
HV_{fuel} = Heating Value of the Fuel
= 19,850 BTU/lb (46.2 MJ/kg) of CNG
= 18,275 BTU/lb (42.5 MJ/kg) of diesel
C_1 = conversion factor

For the hybrid vehicle, however, an additional term was introduced to take into account an aspect of hybrid vehicle that is not present in conventional diesel bus systems: APU/battery pack interaction. APU operation depends on battery pack SOC. Hybrid bus testing can be started at any given battery SOC. In this particular test procedure, it was decided that the cycle would be started with the battery at 100-percent SOC. Since the APU control strategy prohibited engine operation above 85-percent SOC, it was observed, as expected, that no CNG fuel was consumed at the beginning of the driving cycles and that the batteries provided the entire energy required to propel the vehicle. The problem in comparing the diesel-fueled school bus and the hybrid bus is that the change in SOC of the battery pack must be accounted for at the end of the cycle. The energy required to return the battery to the original SOC, combined with the fuel consumed, will yield the total energy required by the vehicle.

$$E_{required} = Sum(m_{fuel\ per\ cycle}) * HV_{fuel} * C_1 + E_{recharge} \quad (2)$$

where

$$E_{recharge} = N_{parallel} * SOC_{change} * E_{ratio} / Eff_{APU} / Eff_{batt} \quad (3)$$

$N_{parallel}$ = number of battery packs in parallel

SOC_{change} = change in battery pack SOC
= $SOC_{initial}$ - (Ahr_{nom} - integral(battery current*dt)/Ahr_{nom})

Eff_{APU} = Average APU efficiency

Eff_{batt} = Average battery charging efficiency

E_{ratio} = Weighted average ratio of electrical energy out of the battery and its corresponding change in SOC for a given length of time

$$E_{ratio} = [\ N_{APU\ \text{"ON"}} *(E_{net\ batt\ out} / SOC_{change})_{w\ APU\ \text{"ON"}} + \ldots \\ N_{APU\ \text{"OFF"}} *(E_{net\ batt\ out} / SOC_{change})_{w\ APU\ \text{"OFF"}}\ ] / (\ N_{APU\ \text{"ON"}} + N_{APU\ \text{"OFF"}}) \quad (4)$$

where, $E_{net\ batt\ out}$ = Integral of ($V_{bus} * I_{batt} * dt$) (5)

$N_{APU\ \text{"ON"}}$ = Number of cycles with APU on
$N_{APU\ \text{"OFF"}}$ = Number of cycles with APU off

The average APU efficiency is included because the analysis assumes that the battery is recharged with the on-board APU. This is a reasonable assumption since the APU controller is designed to maintain SOC between approximately 75 and 85 percent. Average APU efficiency can be estimated directly from the test data by integrating the generator electrical energy delivered and the amount of fuel consumed during a given number of cycles.

$$Eff_{APU} = [\ \text{Integral of } (V_{bus} * I_{gen} * dt)\ ] / [m_{fuel\ consumed} * HV_{fuel} * C_1\ ] \quad (6)$$

Table 7 shows the results of the above analysis for the Allison Series Hybrid Vehicle for the CBD-14 and HDCC driving cycles. The results show that the fuel economy benefits of the hybrid vehicle over the conventional diesel-powered bus vary with driving cycles. In particular, on the CBD-14 driving cycle, the hybrid vehicle had a slight (13 percent) benefit in terms of fuel consumption. On the HDCC driving cycle, the hybrid bus demonstrated much better fuel economy (38 percent).

Table 7. Energy Consumption Analysis for the Allison Hybrid Vehicle		
	CBD-14 Cycle	**HDCC Cycle**
APU Energy Output [Integral of (V_{bus} * I_{gen}) * dt]	9.225 kWh (31,505 BTU)	18.088 kWh (61,775 BTU)
APU Fuel Energy Consumed*1 [$m_{fuel\ consumed}$ * HV_{fuel} * C_1]	28.795 kWh (98,345 BTU)	56.427 kWh (192,715 BTU)
Average APU Efficiency, Eff_{APU}	32%	32%
Net Energy out of the Battery Pack $E_{net\ batt\ out,\ APU\ "OFF"}$	3.4111 kWh (11,650 BTU)	4.249 kWh (14,513 BTU)
Net Change in Battery Pack SOC $SOC_{change\ ,APU\ "OFF"}$	19.4%	26.4%
$E_{ratio,\ APU\ "OFF"}$	600.52	549.7
$N_{APU\ "OFF"}$	3	1
Net Energy out of the Battery Pack $E_{net\ batt\ out,\ APU\ "ON"}$	-0.7554 kWh (-2,580 BTU)*2	1.452 kWh (4,960 BTU)
Net Change in Battery Pack SOC $SOC_{change\ ,APU\ "ON"}$	-2.4%*2	10.9%
$E_{ratio,\ APU\ "ON"}$	1,075	456
$N_{APU\ "ON"}$	6	5
Weighted Average E_{ratio}	916.8	471.6
Total Actual Fuel Energy Consumed [Sum($m_{fuel\ consumed\ per\ cycle}$) * HV_{fuel} * C_1]	40.827 kWh (139,438 BTU)	61.912 kWh (211,450 BTU)
Total Distance Traveled (miles)	18.6	34.09
Total Energy Required for the Hybrid Bus includes Recharge Efficiency (Eq'n 3)	76.731 kWh (262,060 BTU)	94.869 kWh (324,006 BTU)
Hybrid Bus Fuel Consumption (kWh/mile)	**4.12**	**2.78**
Total Actual Fuel Energy Consumed for the Diesel-Fueled School Bus [Sum($m_{fuel\ consumed\ per\ cycle}$) * HV_{fuel} * C_1] (Eq'n 1)	88.226 kWh (301,320 BTU)	152.67 kWh (521,430 BTU)
Diesel Bus Fuel Consumption (kWh/mile)	**4.74**	**4.48**
Fuel Consumption Improvement with Hybrid	**13%**	**38%**

*1 For efficiency calculation, fuel energy of only cycle 4, 5 and 6 were used
*2 Battery Pack was actually being charged

Regenerative Braking Analysis

SwRI used power measurements to analyze regenerative (regen) braking on the hybrid bus. The propulsion power was integrated over the cycle and compared with the integrated regenerative braking power. During the CBD-14 cycle, nearly 20 percent of the propulsion energy applied to the wheel was recovered by regenerative braking while approximately 12 percent of the propulsion energy was recovered by regenerative braking during the heavy duty EPA cycle. The results of this exercise can be seen in Figure 10.

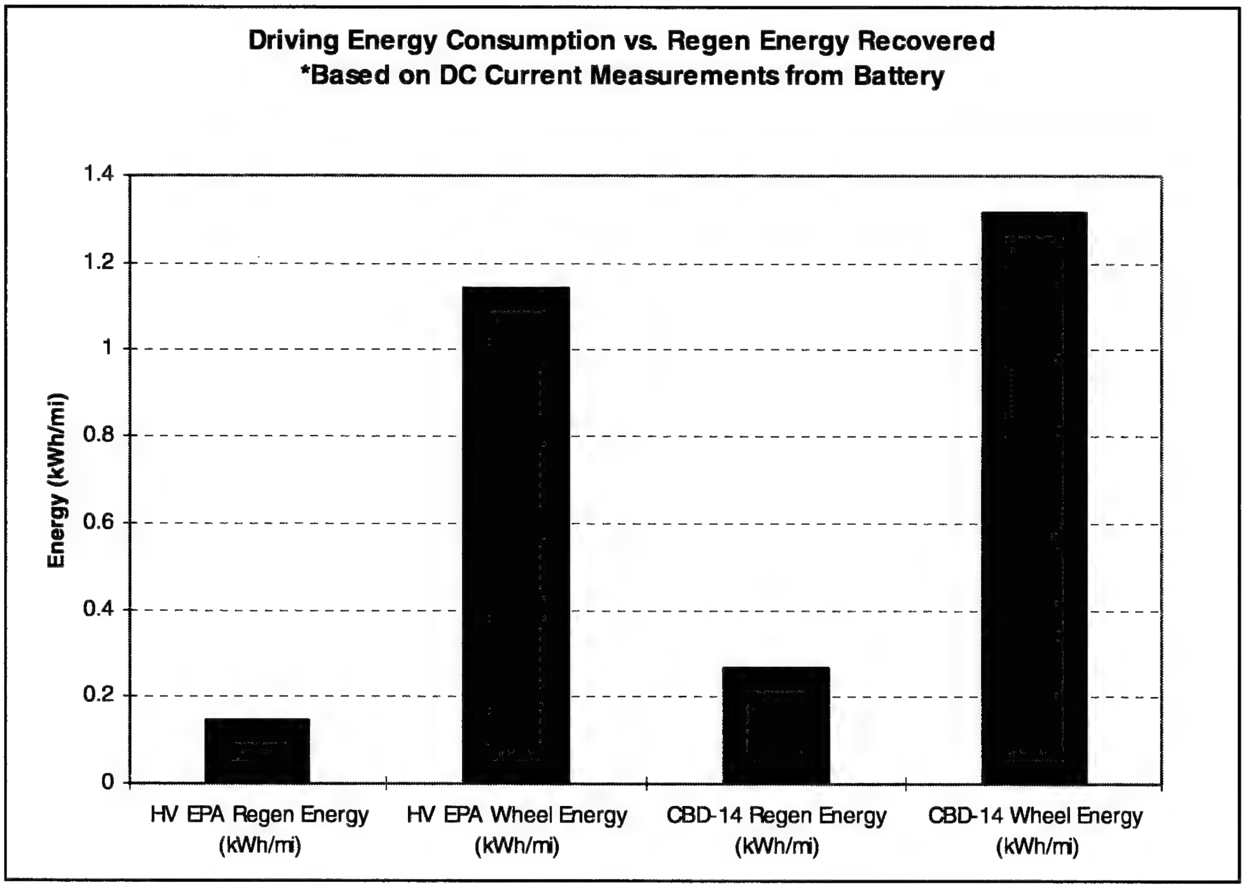

Figure 10. Comparison of Propulsion Energy to Recovered Regen Energy

7.0 SAE METHOD FOR CALCULATING ENERGY CONSUMPTION OF HYBRID VEHICLES

SAE Recommended Practice J1711 provides procedures for energy consumption calculation of light duty hybrid vehicles. SwRI applied the February 26, 1997 draft procedure to the subject vehicle tests to compare it with the procedure developed in section 6.0 of this report. Figure 11 shows an example of the technique. From the series of tests repeated in succession, one was selected which resulted in a net gain in battery SOC and another was chosen which resulted in a net reduction in battery SOC. These two results were interpolated to determine the energy consumption that would occur at a zero-delta SOC. Figure 12 illustrates the energy consumption results determined with the J1711 method along with the diesel bus results. Figures 13 and 14 give the emissions results determined by the same method of SOC adjustment.

The fuel consumption evaluation using the SAE method (J1711 dated 2/26/97) indicates that the hybrid bus consumed 30 percent less fuel on the CBD-14 cycle and 38 percent less fuel on the HDCC (EPA Schedule D) cycle when compared to the diesel bus. Although the EPA cycle fuel consumption results agreed between the two calculation methods (Sections 6.0 and 7.0), the same was not true for the CBD-14 cycle. In the latter case, there was an unexplained difference of 17 percent.

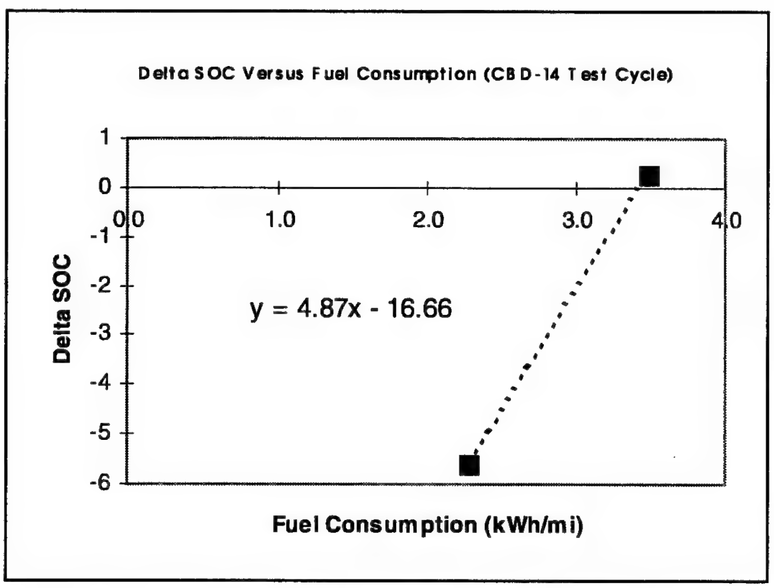

Figure 11. Example of SOC Correction for Fuel Consumption

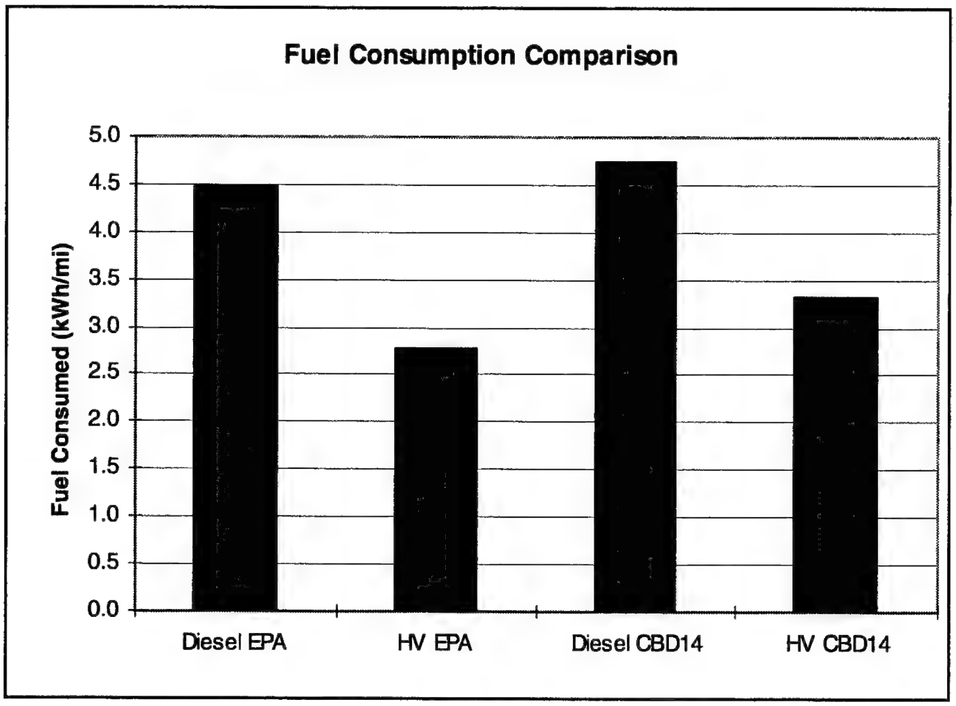

Figure 12. **Comparison of Corrected Fuel Consumption of Hybrid Bus**

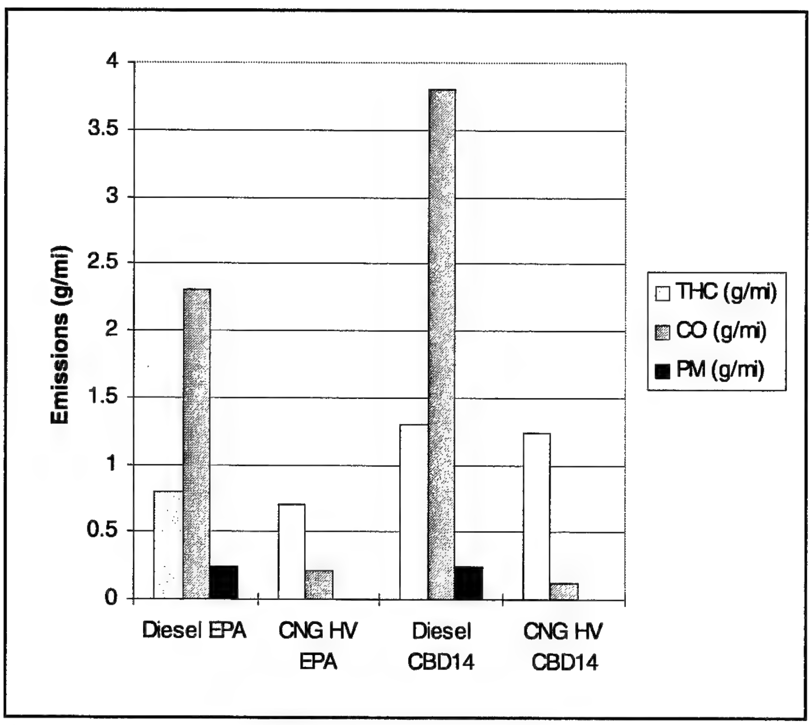

Figure 13. **Comparison of Corrected HC, CO, and PM Emissions of Hybrid Bus**

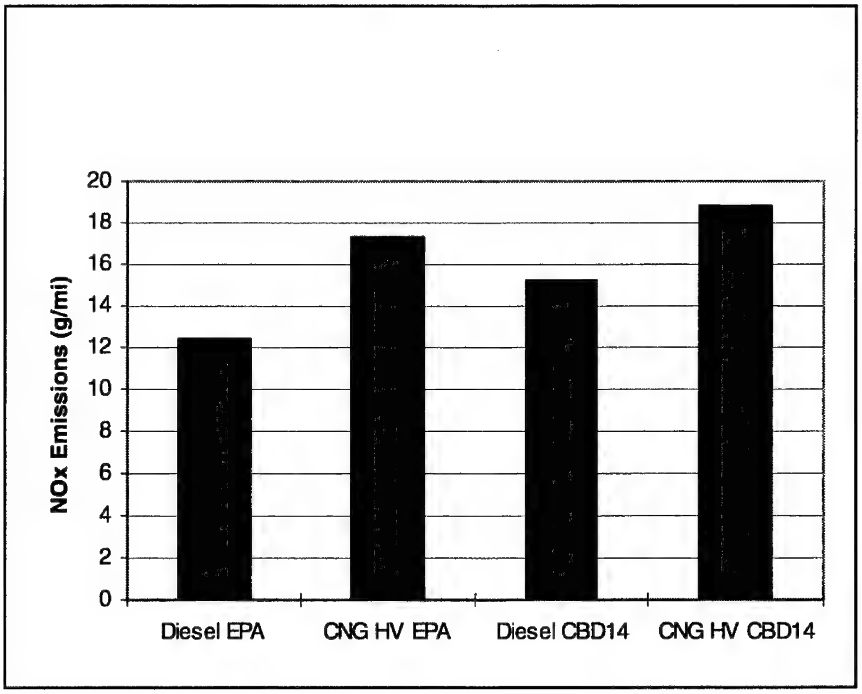

Figure 14. Comparison of Corrected Nox Emissions of Hybrid Bus

8.0 RECOMMENDED TEST AND ANALYSIS PROCEDURE FOR HYBRID VEHICLE FUEL ECONOMY COMPARISON

8.1 Scope

This is a recommended procedure for testing and analyzing the fuel economy of a series hybrid electric vehicle. The procedure assumes, as in most series hybrid platforms that the APU and energy storage device(s) can simultaneously or individually provide power to the traction motors. In addition, the energy storage system can simultaneously accept energy from the APU and the traction motors. Figure 15 shows, as an example, the Allison hybrid bus electrical system that satisfies these criteria.

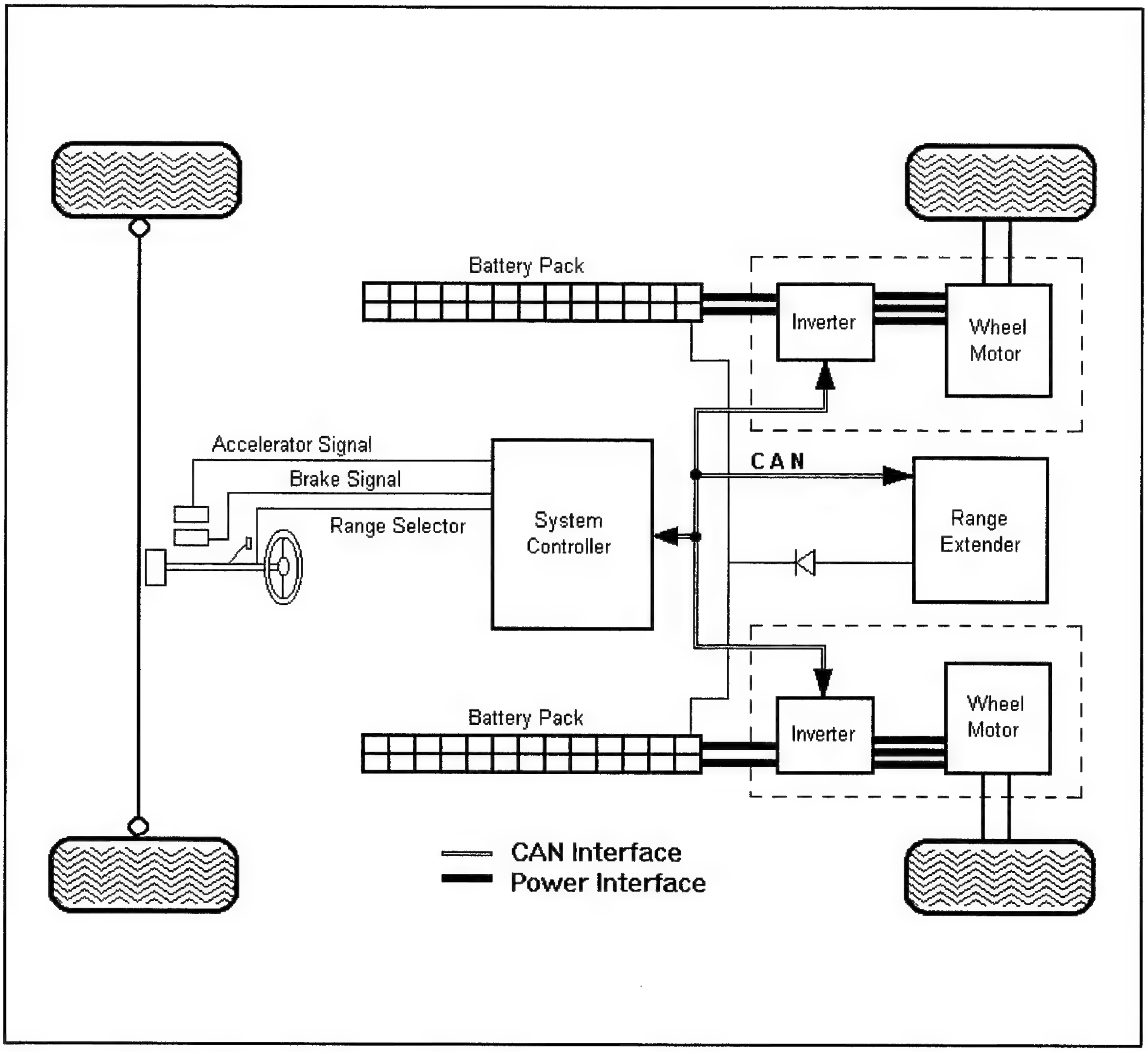

Figure 15. Series Hybrid Electric Vehicle Configuration

8.2 Testing Procedure

8.2.1 Run the baseline vehicle for at least 10 consecutive driving cycles of 500 seconds. Each driving cycle itself can be a composite of multiple cycles. Record accumulated emissions and fuel consumption per cycle. Instantaneous readings are preferred but not necessary.

8.2.2 Repeat the cycles with the hybrid electric vehicle

a. Record accumulated fuel consumption per cycle

b. Record instantaneous DC bus voltage

c. Record instantaneous battery current

d. Record instantaneous generator output current

e. Compute SOC based on the nominal discharge capacity of the battery

8.3 Analysis Procedure

8.3.1 If the APU was able to maintain SOC within the designed threshold, then use Eq'n 1 to compare fuel economy

$$E_{consumed} = Sum(m_{fuel\ per\ cycle}) * HV_{fuel} * C_1 \quad \text{in BTU} \tag{1}$$

where,

m_{fuel} = amount of fuel consumed in kg
HV_{fuel} = Heating Value of the Fuel in BTU/lb
= 19,850 BTU/lb of CNG
= 130,000 BTU/gal of diesel
C_1 = conversion factor

8.3.2 If the APU was unable to maintain SOC within the prescribed threshold, then use Eq'n 2 to compare fuel economy. This equation considers the energy required by the APU to recharge the battery pack.

$$E_{required} = Sum(m_{fuel\ per\ cycle}) * HV_{fuel} * C_1 + E_{recharge} \tag{2}$$

where

$$E_{recharge} = N_{parallel} * SOC_{change} * E_{ratio} / Eff_{APU} \tag{3}$$

$N_{parallel}$ = number of battery packs in parallel

SOC_{change} = change in battery pack SOC
= $SOC_{initial}$ - (Ahr_{nom}- integral(battery current*dt)/Ahr_{nom}

Eff_{APU} = Average APU efficiency

And where,

E_{ratio} = Average ratio of electrical energy out of the battery and its corresponding change in SOC for a given length of time

E_{ratio} =

$$E_{ratio} = N_{APU\ "ON"} * (E_{net\ batt\ out} / SOC_{change})_{w\ APU\ "ON"} + \ldots$$
$$N_{APU\ "OFF"} * (E_{net\ batt\ out} / SOC_{change})_{w\ APU\ "OFF"}] / (N_{APU\ "ON"} + N_{APU\ "OFF"}) \quad (4)$$

where, $E_{net\ batt\ out}$ = Integral of $(V_{bus} * I_{batt}) * dt$ (5)

$N_{APU\ "ON"}$ = Number of cycles with APU on
$N_{APU\ "OFF"}$ = Number of cycles with APU off

$$Eff_{APU} = [\text{ Integral of } (V_{bus} * I_{gen}) * dt\ ] / [m_{fuel\ consumed} * HV_{fuel} * C_1\ ] \quad (6)$$

An alternative to the procedure above is to interpolate between two results as described in Section 7.0.

9.0 SUMMARY

Southwest Research Institute (SwRI) performed heavy-duty chassis dynamometer emissions testing and analyses on a hybrid-powered shuttle bus. The hybrid bus was powered with a CNG-fueled VW 2.0L engine. Exhaust emissions from the hybrid bus were compared to a 1996 model year diesel-powered bus operated over the same driving cycles, and using the same inertia weight and road load as the hybrid bus.

The principal findings of these tests were:

- The aftermarket CNG fuel system installed on the 2.0L VW engine did not function adequately, and as such the exhaust emissions from the hybrid bus could have been much better than were observed.

- Even with the unoptimized CNG fuel system, the exhaust emissions of NMHC, CO, and PM were significantly lower than the diesel bus, but the NO_x emissions were 25 to 30 percent higher than the diesel bus.

- Fuel economy and emissions results were evaluated using State-of-Charge influence correction methods.

- Test results and data analysis suggest that the Allison bus consumes between 13 and 30 percent less fuel on the CBD-14 driving cycle and 38 to 45 percent less fuel on the EPA Schedule D (HDCC) cycle. The variation in percent reduction is linked to the method used for calculating the hybrid bus fuel consumption.

10.0 REFERENCES

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3. France, C.J., et al., "Recommended Practice for Determining Exhaust Emissions from Heavy-Duty Vehicles Under Transient Conditions," EPA Report EPA-AA-SDSB 79-08, PB80-17914- 6, February 1979.
4. California Code of Regulations, Title 13, "California Exhaust Emission Standards and Test Procedures For 1987 and Subsequent Model Heavy-Duty Otto-Cycle Engines and Vehicles," as amended May 15, 1990.
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6. "Methane Measurement Using Gas Chromatography", SAE Recommended Practice, Method J1151, October 1988.
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9. “The Challenges of Developing an Energy, Emissions, and Fuel Economy Test Procedure for Heavy Duty Hybrid Electric Vehicles”, Edward Bass, Terry Ullman, and Edwin Owens, November, 1995

APPENDIX A

Baseline Diesel School Bus Test Results

NEISD Carpenter School Bus No. 578 SwRI Project No. 02-5137-325 updated 20 Nov 97 sgf

Test Date	Test Cycle / #	HC g/mi	CO g/mi	NOx g/mi	PM g/mi	CO2 g/mi	MPG	Energy Cons. (BTU/mi)	Fuel grams	Miles
19 mar 97	cold cbd - 1	1.44	4.99	18.23	0.311	1,391	7.32	17,756	1,734	3.93
19 mar 97	hot cbd - 2	1.25	3.76	14.73	0.260	1,260	8.09	16,064	1,586	3.97
20 mar 97	hot cb2 - 6	1.21	3.17	14.46	0.219	1,229	8.30	15,659	1,566	4.02
24 mar 97	cold cbd - 7	2.09	5.58	17.27	0.353	1,409	7.21	18,020	1,761	3.93
24 mar 97	hot cb2 - 8	1.32	3.80	15.23	0.243	1,247	8.18	15,901	1,597	4.04
Average CBD Composite =		**1.3**	**3.8**	**15.2**	**0.25**	**1,267**	**8.1**	**16,162**		
20 mar 97	cold hdcc - 4	0.76	3.20	13.29	0.258	1,308	7.81	16,646	2,306	5.57
20 mar 97	hot hdcc - 5	0.70	2.00	11.87	0.192	1,160	8.82	14,745	2,041	5.57
19 mar 97	hot hdcc - 3	0.80	2.20	12.73	0.260	1,240	8.25	15,764	2,186	5.58
24 mar 97	hot hdcc - 9	0.85	2.13	12.21	0.257	1,155	8.86	14,680	2,011	5.51
Average HDCC Composite =		**0.8**	**2.3**	**12.4**	**0.24**	**1,203**	**8.5**	**15,289**		

based on a diesel fuel LHV = 130,000 BTU/gal

g/lb fuel

	HC g/lb	CO g/lb	NOx g/lb	PM g/lb	CO2 g/lb
cold cbd - 1	1.48	5.14	18.77	0.32	1,433
hot cbd - 2	1.42	4.28	16.77	0.30	1,434
hot cb2 - 6	1.41	3.70	16.88	0.26	1,435
cold cbd - 7	2.12	5.66	17.52	0.36	1,430
hot cb2 - 8	1.52	4.37	17.51	0.28	1,434
cold hdcc - 4	0.83	3.51	14.60	0.28	1,437
hot hdcc - 5	0.87	2.48	14.72	0.24	1,439
hot hdcc - 3	0.93	2.55	14.77	0.30	1,438
hot hdcc - 9	1.06	2.65	15.21	0.32	1,438

g/hp-hr @ an assumed engine bsfc of 0.43 lb/hp-hr

	HC g/hp-hr	CO g/hp-hr	NOx g/hp-hr	PM g/hp-hr	PM g/hp-hr
cold cbd - 1	0.64	2.21	8.07	0.14	616
hot cbd - 2	0.61	1.84	7.21	0.13	617
hot cb2 - 6	0.61	1.59	7.26	0.11	617
cold cbd - 7	0.91	2.43	7.54	0.15	615
hot cb2 - 8	0.65	1.88	7.53	0.12	617
cold hdcc - 4	0.36	1.51	6.28	0.12	618
hot hdcc - 5	0.37	1.07	6.33	0.10	619
hot hdcc - 3	0.40	1.10	6.35	0.13	619
hot hdcc - 9	0.46	1.14	6.54	0.14	618

COLD CBD VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325

PROGRAM = SOR09S

ẞST NO. 1 RUN 1	VEHICLE NO. #578	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 96 CARPENTER	DATE 3/19/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 7.3 L(445. CID)	BAG CART NO. 2	DIESEL EM-2482-F
TRANSMISSION AT	DYNO NO. 4	ODOMETER 30578. KM(19000. MILES)
GVW = 13154. KG (29000. LBS)	CVS NO. 11	HCR = 1.81
BAROMETER 746.76 MM HG(29.40 IN HG)	DRY BULB TEMP. 21.1 DEG C(70.0 DEG F)	
RELATIVE HUMIDITY 77. PCT	ABS. HUMIDITY 12.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.0

BAG RESULTS

TEST CYCLE	COLD CBD
RUN TIME SECONDS	1117.6
TOT. BLOWER RATE SCMM (SCFM)	59.77 (2110.5)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.55)
TOT FLOW STD. CU. METRES(SCF)	1115.2 (39378.)
HC SAMPLE METER/RANGE/PPM	20.6/1042/ 20.36
HC BCKGRD METER/RANGE/PPM	12.0/1042/ 11.85
CO SAMPLE METER/RANGE/PPM	13.3/ 12/ 15.58
CO BCKGRD METER/RANGE/PPM	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	78.3/ 13/.3081
CO2 BCKGRD METER/RANGE/PCT	18.3/ 13/.0414
NOX SAMPLE METER/RANGE/PPM	33.0/1041/33.13
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .40
DILUTION FACTOR	40.10
HC CONCENTRATION PPM	8.80
CO CONCENTRATION PPM	15.11
CO2 CONCENTRATION PCT	.2677
NOX CONCENTRATION PPM	32.65
HC MASS GRAMS	5.639
CO MASS GRAMS	19.613
CO2 MASS GRAMS	5464.95
NOX MASS GRAMS	71.613
MASS OF FUEL BURNED GRAMS	1733.89
MEASURED DISTANCE KM (MILES)	6.319 (3.928)
FUEL CONSUMPTION LB/MILE	32.20 (.137)
HC GRAMS/KM (GRAMS/MILE)	.89 (1.44)
CO GRAMS/KM (GRAMS/MILE)	3.10 (4.99)
CO2 GRAMS/KM (GRAMS/MILE)	864.8 (1391.4)
NOX GRAMS/KM (GRAMS/MILE)	11.33 (18.23)

PARTICULATE RATE

GRAMS/TEST =	1.221
GRAMS/KG FUEL =	.70
GRAMS/KM =	.19
GRAMS/MILE =	.31
FILTER EFF. =	100.00

HOT CBD VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325

PROGRAM = SOR09S

.ST NO. 2 RUN 1	VEHICLE NO. #578	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 96 CARPENTER	DATE 3/19/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 7.3 L(445. CID)	BAG CART NO. 2	DIESEL EM-2482-F
TRANSMISSION AT	DYNO NO. 4	ODOMETER 30578. KM(19000. MILES)
GVW = 13154. KG (29000. LBS)	CVS NO. 11	HCR = 1.81
BAROMETER 746.25 MM HG(29.38 IN HG)	DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)	
RELATIVE HUMIDITY 26. PCT	ABS. HUMIDITY 5.5 GM/KG	NOX HUMIDITY CORRECTION FACTOR .91

BAG RESULTS

TEST CYCLE	HOT CBD
RUN TIME SECONDS	1119.5
TOT. BLOWER RATE SCMM (SCFM)	61.69 (2178.2)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.52)
TOT FLOW STD. CU. METRES(SCF)	1152.9 (40708.)
HC SAMPLE METER/RANGE/PPM	19.3/1042/ 19.07
HC BCKGRD METER/RANGE/PPM	12.0/1042/ 11.85
CO SAMPLE METER/RANGE/PPM	9.4/ 12/ 11.43
CO BCKGRD METER/RANGE/PPM	.1/ 12/ .14
CO2 SAMPLE METER/RANGE/PCT	73.4/ 13/.2758
CO2 BCKGRD METER/RANGE/PCT	17.6/ 13/.0396
NOX SAMPLE METER/RANGE/PPM	29.3/1041/29.42
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30
DILUTION FACTOR	44.81
HC CONCENTRATION PPM	7.48
CO CONCENTRATION PPM	11.14
CO2 CONCENTRATION PCT	.2371
NOX CONCENTRATION PPM	29.05
HC MASS GRAMS	4.954
CO MASS GRAMS	14.950
CO2 MASS GRAMS	5005.05
NOX MASS GRAMS	58.516
MASS OF FUEL BURNED GRAMS	1586.27
MEASURED DISTANCE KM (MILES)	6.392 (3.972)
FUEL CONSUMPTION LB/MILE	29.13 (.124)
HC GRAMS/KM (GRAMS/MILE)	.78 (1.25)
CO GRAMS/KM (GRAMS/MILE)	2.34 (3.76)
CO2 GRAMS/KM (GRAMS/MILE)	783.0 (1259.9)
NOX GRAMS/KM (GRAMS/MILE)	9.15 (14.73)

PARTICULATE RATE

GRAMS/TEST =	1.032
GRAMS/KG FUEL =	.65
GRAMS/KM =	.16
GRAMS/MILE =	.26
FILTER EFF. =	100.00

HOT HDCC VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

.EST NO. 3 RUN 1	VEHICLE NO. #578	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 96 CARPENTER	DATE 3/19/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP
ENGINE 7.3 L(445. CID)	BAG CART NO. 2	DIESEL EM-2482-F
TRANSMISSION AT	DYNO NO. 4	ODOMETER 30578. KM(19000. MILES)
GVW = 13154. KG (29000. LBS)	CVS NO. 11	HCR = 1.81
BAROMETER 745.74 MM HG(29.36 IN HG)	DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)	
RELATIVE HUMIDITY 27. PCT	ABS. HUMIDITY 5.5 GM/KG	NOX HUMIDITY CORRECTION FACTOR .

BAG RESULTS

TEST CYCLE	HOT HDCC
RUN TIME SECONDS	1060.9
TOT. BLOWER RATE SCMM (SCFM)	64.25 (2268.6)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.50)
TOT FLOW STD. CU. METRES(SCF)	1137.7 (40174.)
HC SAMPLE METER/RANGE/PPM	18.5/1042/ 18.30
HC BCKGRD METER/RANGE/PPM	12.0/1042/ 11.85
CO SAMPLE METER/RANGE/PPM	7.7/ 12/ 9.53
CO BCKGRD METER/RANGE/PPM	.1/ 12/ .14
CO2 SAMPLE METER/RANGE/PCT	86.8/ 13/.3700
CO2 BCKGRD METER/RANGE/PCT	17.4/ 13/.0391
NOX SAMPLE METER/RANGE/PPM	36.0/1041/36.13
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30
DILUTION FACTOR	33.53
HC CONCENTRATION PPM	6.80
CO CONCENTRATION PPM	9.25
CO2 CONCENTRATION PCT	.3321
NOX CONCENTRATION PPM	35.71
HC MASS GRAMS	4.444
CO MASS GRAMS	12.252
CO2 MASS GRAMS	6916.77
NOX MASS GRAMS	70.988
MASS OF FUEL BURNED GRAMS	2185.61
MEASURED DISTANCE KM (MILES)	8.973 (5.577)
FUEL CONSUMPTION LB/MILE	28.58 (.122)
HC GRAMS/KM (GRAMS/MILE)	.50 (.80)
CO GRAMS/KM (GRAMS/MILE)	1.37 (2.20)
CO2 GRAMS/KM (GRAMS/MILE)	770.8 (1240.2)
NOX GRAMS/KM (GRAMS/MILE)	7.91 (12.73)

PARTICULATE RATE
GRAMS/TEST = 1.452
GRAMS/KG FUEL = .66
GRAMS/KM = .16
GRAMS/MILE = .26
FILTER EFF. = 100.00

COLD HDCC VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325

PROGRAM = SOR09S

.EST NO. 4 RUN 1	VEHICLE NO. #578	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 96 CARPENTER	DATE 3/20/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 7.3 L(445. CID)	BAG CART NO. 2	DIESEL EM-2482-F
TRANSMISSION AT	DYNO NO. 4	ODOMETER 32026. KM(19900. MILES)
GVW = 13154. KG (29000. LBS)	CVS NO. 11	HCR = 1.81

BAROMETER 740.66 MM HG(29.16 IN HG)
DRY BULB TEMP. 26.7 DEG C(80.0 DEG F)
RELATIVE HUMIDITY 25. PCT
ABS. HUMIDITY 5.7 GM/KG
NOX HUMIDITY CORRECTION FACTOR .92

BAG RESULTS

TEST CYCLE	COLD HDCC
RUN TIME SECONDS	1062.9
TOT. BLOWER RATE SCMM (SCFM)	60.88 (2149.6)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.42)
TOT FLOW STD. CU. METRES(SCF)	1080.2 (38140.)
HC SAMPLE METER/RANGE/PPM	18.5/1042/ 18.30
HC BCKGRD METER/RANGE/PPM	12.0/1042/ 11.85
CO SAMPLE METER/RANGE/PPM	12.2/ 12/ 14.43
CO BCKGRD METER/RANGE/PPM	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	91.5/ 13/.4078
CO2 BCKGRD METER/RANGE/PCT	17.9/ 13/.0404
NOX SAMPLE METER/RANGE/PPM	39.5/1041/39.58
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30
DILUTION FACTOR	30.40
HC CONCENTRATION PPM	6.84
CO CONCENTRATION PPM	14.20
CO2 CONCENTRATION PCT	.3687
NOX CONCENTRATION PPM	39.14
HC MASS GRAMS	4.245
CO MASS GRAMS	17.861
CO2 MASS GRAMS	7292.05
NOX MASS GRAMS	74.046
MASS OF FUEL BURNED GRAMS	2306.19
MEASURED DISTANCE KM (MILES)	8.967 (5.573)
FUEL CONSUMPTION LB/MILE	30.18 (.128)
HC GRAMS/KM (GRAMS/MILE)	.47 (.76)
CO GRAMS/KM (GRAMS/MILE)	1.99 (3.20)
CO2 GRAMS/KM (GRAMS/MILE)	813.2 (1308.4)
NOX GRAMS/KM (GRAMS/MILE)	8.26 (13.29)

PARTICULATE RATE
GRAMS/TEST = 1.436
GRAMS/KG FUEL = .62
GRAMS/KM = .16
GRAMS/MILE = .26
FILTER EFF. = 100.00

HOT HDCC VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325

PROGRAM = SOR09S

EST NO. 5 RUN 1
VEHICLE MODEL 96 CARPENTER
ENGINE 7.3 L(445. CID)
TRANSMISSION AT
GVW = 13154. KG (29000. LBS)

VEHICLE NO. #578
DATE 3/20/97
BAG CART NO. 2
DYNO NO. 4
CVS NO. 11

TEST WEIGHT 6623. KG(14600. LBS)
ACTUAL ROAD LOAD 38.9 KW(52.2 HP
DIESEL EM-2482-F
ODOMETER 32145. KM(19974. MILES)
HCR = 1.81

BAROMETER 740.41 MM HG(29.15 IN HG)
RELATIVE HUMIDITY 25. PCT

DRY BULB TEMP. 26.7 DEG C(80.0 DEG F)
ABS. HUMIDITY 5.7 GM/KG

NOX HUMIDITY CORRECTION FACTOR .

BAG RESULTS

TEST CYCLE	HOT HDCC
RUN TIME SECONDS	1065.9
TOT. BLOWER RATE SCMM (SCFM)	60.97 (2152.7)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.42)
TOT FLOW STD. CU. METRES(SCF)	1084.8 (38303.)
HC SAMPLE METER/RANGE/PPM	18.0/1042/ 17.73
HC BCKGRD METER/RANGE/PPM	12.0/1042/ 11.85
CO SAMPLE METER/RANGE/PPM	7.3/ 12/ 9.08
CO BCKGRD METER/RANGE/PPM	.1/ 12/ .14
CO2 SAMPLE METER/RANGE/PCT	86.1/ 13/.3646
CO2 BCKGRD METER/RANGE/PCT	17.9/ 13/.0404
NOX SAMPLE METER/RANGE/PPM	35.1/1041/35.20
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30
DILUTION FACTOR	34.03
HC CONCENTRATION PPM	6.23
CO CONCENTRATION PPM	8.81
CO2 CONCENTRATION PCT	.3254
NOX CONCENTRATION PPM	34.79
HC MASS GRAMS	3.881
CO MASS GRAMS	11.121
CO2 MASS GRAMS	6461.83
NOX MASS GRAMS	66.096
MASS OF FUEL BURNED GRAMS	2041.42
MEASURED DISTANCE KM (MILES)	8.960 (5.569)
FUEL CONSUMPTION LB/MILE	26.74 (.114)
HC GRAMS/KM (GRAMS/MILE)	.43 (.70)
CO GRAMS/KM (GRAMS/MILE)	1.24 (2.00)
CO2 GRAMS/KM (GRAMS/MILE)	721.2 (1160.3)
NOX GRAMS/KM (GRAMS/MILE)	7.38 (11.87)

PARTICULATE RATE

GRAMS/TEST =	1.070
GRAMS/KG FUEL =	.52
GRAMS/KM =	.12
GRAMS/MILE =	.19
FILTER EFF. =	100.00

HOT CBD VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. 6 RUN 1	VEHICLE NO. #578	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 96 CARPENTER	DATE 3/20/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 7.3 L(445. CID)	BAG CART NO. 2	DIESEL EM-2482-F
TRANSMISSION AT	DYNO NO. 4	ODOMETER 32155. KM(19980. MILES)
GVW = 13154. KG (29000. LBS)	CVS NO. 11	HCR = 1.81
BAROMETER 739.90 MM HG(29.13 IN HG)	DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)	
RELATIVE HUMIDITY 26. PCT	ABS. HUMIDITY 5.6 GM/KG	NOX HUMIDITY CORRECTION FACTOR .92

BAG RESULTS

TEST CYCLE	HOT CBD
RUN TIME SECONDS	1118.6
TOT. BLOWER RATE SCMM (SCFM)	61.03 (2154.9)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.43)
TOT FLOW STD. CU. METRES(SCF)	1139.6 (40238.)
HC SAMPLE METER/RANGE/PPM	19.2/1042/ 19.00
HC BCKGRD METER/RANGE/PPM	12.0/1042/ 11.85
CO SAMPLE METER/RANGE/PPM	8.0/ 12/ 9.87
CO BCKGRD METER/RANGE/PPM	.1/ 12/ .14
CO2 SAMPLE METER/RANGE/PCT	73.3/ 13/.2752
CO2 BCKGRD METER/RANGE/PCT	17.4/ 13/.0391
NOX SAMPLE METER/RANGE/PPM	29.4/1041/29.52
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30
DILUTION FACTOR	44.94
HC CONCENTRATION PPM	7.41
CO CONCENTRATION PPM	9.60
CO2 CONCENTRATION PCT	.2370
NOX CONCENTRATION PPM	29.15
HC MASS GRAMS	4.848
CO MASS GRAMS	12.738
CO2 MASS GRAMS	4944.68
NOX MASS GRAMS	58.173
MASS OF FUEL BURNED GRAMS	1566.09
MEASURED DISTANCE KM (MILES)	6.472 (4.023)
FUEL CONSUMPTION LB/MILE	28.40 (.121)
HC GRAMS/KM (GRAMS/MILE)	.75 (1.21)
CO GRAMS/KM (GRAMS/MILE)	1.97 (3.17)
CO2 GRAMS/KM (GRAMS/MILE)	764.0 (1229.2)
NOX GRAMS/KM (GRAMS/MILE)	8.99 (14.46)

PARTICULATE RATE
GRAMS/TEST = .883
GRAMS/KG FUEL = .56
GRAMS/KM = .14
GRAMS/MILE = .22
FILTER EFF. = 100.00

COLD CBD VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

ST NO. 7 RUN 1	VEHICLE NO. #578	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 96 CARPENTER	DATE 3/24/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 7.3 L(445. CID)	BAG CART NO. 2	DIESEL EM-2482-F
TRANSMISSION AT	DYNO NO. 4	ODOMETER 32161. KM(19984. MILES)
GVW = 13154. KG (29000. LBS)	CVS NO. 11	HCR = 1.81

BAROMETER 736.85 MM HG(29.01 IN HG) DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)
RELATIVE HUMIDITY 64. PCT ABS. HUMIDITY 13.1 GM/KG NOX HUMIDITY CORRECTION FACTOR 1.0

BAG RESULTS

TEST CYCLE	COLD CBD
RUN TIME SECONDS	1120.2
TOT. BLOWER RATE SCMM (SCFM)	60.45 (2134.4)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.44)
TOT FLOW STD. CU. METRES(SCF)	1130.4 (39914.)
HC SAMPLE METER/RANGE/PPM	18.2/1042/ 17.98
HC BCKGRD METER/RANGE/PPM	5.5/1042/ 5.43
CO SAMPLE METER/RANGE/PPM	14.8/ 12/ 17.12
CO BCKGRD METER/RANGE/PPM	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	78.0/ 13/.3060
CO2 BCKGRD METER/RANGE/PCT	17.5/ 13/.0393
NOX SAMPLE METER/RANGE/PPM	30.2/1041/30.33
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .20
DILUTION FACTOR	40.38
HC CONCENTRATION PPM	12.68
CO CONCENTRATION PPM	16.67
CO2 CONCENTRATION PCT	.2677
NOX CONCENTRATION PPM	30.05
HC MASS GRAMS	8.232
CO MASS GRAMS	21.939
CO2 MASS GRAMS	5539.25
NOX MASS GRAMS	67.905
MASS OF FUEL BURNED GRAMS	1760.99
MEASURED DISTANCE KM (MILES)	6.325 (3.931)
FUEL CONSUMPTION LB/MILE	32.68 (.139)
HC GRAMS/KM (GRAMS/MILE)	1.30 (2.09)
CO GRAMS/KM (GRAMS/MILE)	3.47 (5.58)
CO2 GRAMS/KM (GRAMS/MILE)	875.8 (1409.1)
NOX GRAMS/KM (GRAMS/MILE)	10.74 (17.27)

PARTICULATE RATE

GRAMS/TEST =	1.386
GRAMS/KG FUEL =	.79
GRAMS/KM =	.22
GRAMS/MILE =	.35
FILTER EFF. =	100.00

HOT CBD VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. 8 RUN 1	VEHICLE NO. #578	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 96 CARPENTER	DATE 3/24/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 7.3 L(445. CID)	BAG CART NO. 2	DIESEL EM-2482-F
TRANSMISSION AT	DYNO NO. 4	ODOMETER 32168. KM(19988. MILES)
GVW = 13154. KG (29000. LBS)	CVS NO. 11	HCR = 1.81
BAROMETER 736.35 MM HG(28.99 IN HG)	DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)	
RELATIVE HUMIDITY 60. PCT	ABS. HUMIDITY 12.7 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.04

BAG RESULTS

TEST CYCLE	HOT CBD
RUN TIME SECONDS	1121.1
TOT. BLOWER RATE SCMM (SCFM)	60.31 (2129.5)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.41)
TOT FLOW STD. CU. METRES(SCF)	1128.7 (39853.)
HC SAMPLE METER/RANGE/PPM	13.9/1042/ 13.74
HC BCKGRD METER/RANGE/PPM	5.7/1042/ 5.63
CO SAMPLE METER/RANGE/PPM	9.9/ 12/ 11.97
CO BCKGRD METER/RANGE/PPM	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	74.4/ 13/.2822
CO2 BCKGRD METER/RANGE/PCT	17.5/ 13/.0393
NOX SAMPLE METER/RANGE/PPM	27.6/1041/27.72
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .20
DILUTION FACTOR	43.88
HC CONCENTRATION PPM	8.24
CO CONCENTRATION PPM	11.68
CO2 CONCENTRATION PCT	.2438
NOX CONCENTRATION PPM	27.45
HC MASS GRAMS	5.340
CO MASS GRAMS	15.343
CO2 MASS GRAMS	5037.49
NOX MASS GRAMS	61.510
MASS OF FUEL BURNED GRAMS	1597.05
MEASURED DISTANCE KM (MILES)	6.500 (4.040)
FUEL CONSUMPTION LB/MILE	28.83 (.123)
HC GRAMS/KM (GRAMS/MILE)	.82 (1.32)
CO GRAMS/KM (GRAMS/MILE)	2.36 (3.80)
CO2 GRAMS/KM (GRAMS/MILE)	774.9 (1246.9)
NOX GRAMS/KM (GRAMS/MILE)	9.46 (15.23)

PARTICULATE RATE
GRAMS/TEST = .981
GRAMS/KG FUEL = .61
GRAMS/KM = .15
GRAMS/MILE = .24
FILTER EFF. = 100.00

HOT HDCC VEHICLE EMISSIONS RESULTS
PROJECT 08-5137-325

PROGRAM = SOR09S

TEST NO. 9 RUN 1	VEHICLE NO. #578	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 96 CARPENTER	DATE 3/24/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 7.3 L(445. CID)	BAG CART NO. 2	DIESEL EM-2482-F
TRANSMISSION AT	DYNO NO. 4	ODOMETER 32174. KM(19992. MILES)
GVW = 13154. KG (29000. LBS)	CVS NO. 11	HCR = 1.81
BAROMETER 735.84 MM HG(28.97 IN HG)	DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)	
RELATIVE HUMIDITY 60. PCT	ABS. HUMIDITY 13.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.05

BAG RESULTS

TEST CYCLE	HOT HDCC
RUN TIME SECONDS	1063.0
TOT. BLOWER RATE SCMM (SCFM)	60.14 (2123.7)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.10 (3.40)
TOT FLOW STD. CU. METRES(SCF)	1067.3 (37685.)
HC SAMPLE METER/RANGE/PPM	12.8/1042/ 12.66
HC BCKGRD METER/RANGE/PPM	5.2/1042/ 5.14
CO SAMPLE METER/RANGE/PPM	8.2/ 12/ 10.09
CO BCKGRD METER/RANGE/PPM	.3/ 12/ .41
CO2 SAMPLE METER/RANGE/PCT	86.0/ 13/.3638
CO2 BCKGRD METER/RANGE/PCT	17.5/ 13/.0393
NOX SAMPLE METER/RANGE/PPM	31.9/1041/32.03
NOX BCKGRD METER/RANGE/PPM	.4/ 2/ .40
DILUTION FACTOR	34.14
HC CONCENTRATION PPM	7.67
CO CONCENTRATION PPM	9.44
CO2 CONCENTRATION PCT	.3256
NOX CONCENTRATION PPM	31.54
HC MASS GRAMS	4.702
CO MASS GRAMS	11.730
CO2 MASS GRAMS	6362.35
NOX MASS GRAMS	67.305
MASS OF FUEL BURNED GRAMS	2011.26
MEASURED DISTANCE KM (MILES)	8.867 (5.511)
FUEL CONSUMPTION LB/MILE	26.62 (.113)
HC GRAMS/KM (GRAMS/MILE)	.53 (.85)
CO GRAMS/KM (GRAMS/MILE)	1.32 (2.13)
CO2 GRAMS/KM (GRAMS/MILE)	717.5 (1154.5)
NOX GRAMS/KM (GRAMS/MILE)	7.59 (12.21)

PARTICULATE RATE

GRAMS/TEST =	1.417
GRAMS/KG FUEL =	.70
GRAMS/KM =	.16
GRAMS/MILE =	.26
FILTER EFF. =	100.00

APPENDIX B:

Hybrid Bus Test Results Over CBD Cycle

Test Date = 8/14/97 = With Closed-Loop IMPCO & new catalyst

CBD Test No.	CNG Fuel grams	Cycle miles	Test Dur. sec.	THC g/mi	NMHC g/mi	CO g/mi	NOx g/mi	PM g/mi	CO2 g/mi	BTU/mi
1	0	2.05	555	0	0	0	0	0	0	0
2	0	2.05	555	0	0	0	0	0	0	0
3	0	2.05	555	0	0	0	0	0	0	0
4	364	2.05	543	1.6	0.30	0.17	11.4	0	488.1	7,745
5	577	2.08	555	1.3	0.29	0.13	19.4	0	767.1	12,126
6	568	2.10	560	1.4	0.34	0.05	20.3	0	747.6	11,814
7	568	2.06	557	1.4	0.36	0.09	21.7	0	759.8	12,011
8	553	2.09	558	1.3	0.34	0.13	20.0	0	730.8	11,552
9	563	2.07	559	1.3	0.32	0.13	19.7	0	751.5	11,877

Updated 11/20/97 sgf

LHV = 19,850 BTU/lb

CBD VEHICLE EMISSIONS RESULTS

PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. CBD-4 RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/14/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80

BAROMETER 740.18 MM HG(29.14 IN HG)	DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)	
RELATIVE HUMIDITY 87. PCT	ABS. HUMIDITY 16.8 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.25

BAG RESULTS

TEST CYCLE	CBD
RUN TIME SECONDS	542.7
TOT. BLOWER RATE SCMM (SCFM)	61.42 (2168.8)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	555.6 (19617.)
HC SAMPLE METER/RANGE/PPM	12.6/ 2/ 12.59
HC BCKGRD METER/RANGE/PPM	3.9/ 2/ 3.90
CO SAMPLE METER/RANGE/PPM	.9/ 12/ 1.22
CO BCKGRD METER/RANGE/PPM	.5/ 12/ .68
CO2 SAMPLE METER/RANGE/PCT	46.4/ 13/.1358
CO2 BCKGRD METER/RANGE/PCT	16.9/ 13/.0378
NOX SAMPLE METER/RANGE/PPM	71.3/ 1/17.83
NOX BCKGRD METER/RANGE/PPM	.6/ 1/ .15
DILUTION FACTOR	70.79
HC CONCENTRATION PPM	8.75
CO CONCENTRATION PPM	.53
CO2 CONCENTRATION PCT	.0985
NOX CONCENTRATION PPM	17.68
HC MASS GRAMS	3.197
CO MASS GRAMS	.340
CO2 MASS GRAMS	1002.28
NOX MASS GRAMS	23.502
MASS OF FUEL BURNED GRAMS	364.27
MEASURED DISTANCE KM (MILES)	3.304 (2.054)
FUEL CONSUMPTION LB/MILE	12.94 (.055)
HC GRAMS/KM (GRAMS/MILE)	.97 (1.56)
CO GRAMS/KM (GRAMS/MILE)	.10 (.17)
CO2 GRAMS/KM (GRAMS/MILE)	303.3 (488.1)
NOX GRAMS/KM (GRAMS/MILE)	7.11 (11.44)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

CBD VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. CBD-5 RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/14/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80

BAROMETER 740.21 MM HG(29.14 IN HG) DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)
RELATIVE HUMIDITY 83. PCT ABS. HUMIDITY 16.5 GM/KG NOX HUMIDITY CORRECTION FACTOR 1.24
BAG RESULTS

TEST CYCLE	CBD
RUN TIME SECONDS	554.9
TOT. BLOWER RATE SCMM (SCFM)	61.39 (2167.8)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	567.8 (20049.)
HC SAMPLE METER/RANGE/PPM	11.5/ 2/ 11.49
HC BCKGRD METER/RANGE/PPM	4.1/ 2/ 4.10
CO SAMPLE METER/RANGE/PPM	.8/ 12/ 1.08
CO BCKGRD METER/RANGE/PPM	.5/ 12/ .68
CO2 SAMPLE METER/RANGE/PCT	58.3/ 13/.1904
CO2 BCKGRD METER/RANGE/PCT	16.9/ 13/.0378
NOX SAMPLE METER/RANGE/PPM	30.0/ 2/30.11
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	50.66
HC CONCENTRATION PPM	7.48
CO CONCENTRATION PPM	.40
CO2 CONCENTRATION PCT	.1534
NOX CONCENTRATION PPM	30.01
HC MASS GRAMS	2.792
CO MASS GRAMS	.264
CO2 MASS GRAMS	1594.33
NOX MASS GRAMS	40.274
MASS OF FUEL BURNED GRAMS	577.00
MEASURED DISTANCE KM (MILES)	3.344 (2.078)
FUEL CONSUMPTION LB/MILE	20.25 (.086)
HC GRAMS/KM (GRAMS/MILE)	.83 (1.34)
CO GRAMS/KM (GRAMS/MILE)	.08 (.13)
CO2 GRAMS/KM (GRAMS/MILE)	476.8 (767.1)
NOX GRAMS/KM (GRAMS/MILE)	12.04 (19.38)

PARTICULATE RATE
GRAMS/TEST = .000
GRAMS/KG FUEL = .00
GRAMS/KM = .00
GRAMS/MILE = .00
FILTER EFF. = 100.00

CBD VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. CBD-6 RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/14/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80
BAROMETER 740.26 MM HG(29.14 IN HG)	DRY BULB TEMP. 25.0 DEG C(77.0 DEG F)	
RELATIVE HUMIDITY 79. PCT	ABS. HUMIDITY 16.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.22

BAG RESULTS

TEST CYCLE	CBD
RUN TIME SECONDS	560.1
TOT. BLOWER RATE SCMM (SCFM)	61.39 (2167.8)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	573.1 (20236.)
HC SAMPLE METER/RANGE/PPM	11.5/ 2/ 11.49
HC BCKGRD METER/RANGE/PPM	4.0/ 2/ 4.00
CO SAMPLE METER/RANGE/PPM	.8/ 12/ 1.08
CO BCKGRD METER/RANGE/PPM	.7/ 12/ .95
CO2 SAMPLE METER/RANGE/PCT	57.6/ 13/.1869
CO2 BCKGRD METER/RANGE/PCT	17.0/ 13/.0380
NOX SAMPLE METER/RANGE/PPM	31.8/ 2/31.91
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	51.60
HC CONCENTRATION PPM	7.57
CO CONCENTRATION PPM	.14
CO2 CONCENTRATION PCT	.1496
NOX CONCENTRATION PPM	31.81
HC MASS GRAMS	2.854
CO MASS GRAMS	.095
CO2 MASS GRAMS	1569.74
NOX MASS GRAMS	42.600
MASS OF FUEL BURNED GRAMS	568.11
MEASURED DISTANCE KM (MILES)	3.379 (2.100)
FUEL CONSUMPTION LB/MILE	19.73 (.084)
HC GRAMS/KM (GRAMS/MILE)	.84 (1.36)
CO GRAMS/KM (GRAMS/MILE)	.03 (.05)
CO2 GRAMS/KM (GRAMS/MILE)	464.6 (747.6)
NOX GRAMS/KM (GRAMS/MILE)	12.61 (20.29)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

CBD VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. CBD-7 RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/14/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80

BAROMETER 740.26 MM HG(29.14 IN HG)	DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)	
RELATIVE HUMIDITY 80. PCT	ABS. HUMIDITY 17.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.27

BAG RESULTS

TEST CYCLE	CBD
RUN TIME SECONDS	556.7
TOT. BLOWER RATE SCMM (SCFM)	61.31 (2164.8)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	568.8 (20085.)
HC SAMPLE METER/RANGE/PPM	11.5/ 2/ 11.49
HC BCKGRD METER/RANGE/PPM	4.0/ 2/ 4.00
CO SAMPLE METER/RANGE/PPM	.8/ 12/ 1.08
CO BCKGRD METER/RANGE/PPM	.6/ 12/ .81
CO2 SAMPLE METER/RANGE/PCT	57.7/ 13/.1874
CO2 BCKGRD METER/RANGE/PCT	16.8/ 13/.0375
NOX SAMPLE METER/RANGE/PPM	32.5/ 2/32.61
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	51.47
HC CONCENTRATION PPM	7.57
CO CONCENTRATION PPM	.27
CO2 CONCENTRATION PCT	.1506
NOX CONCENTRATION PPM	32.52
HC MASS GRAMS	2.833
CO MASS GRAMS	.179
CO2 MASS GRAMS	1568.49
NOX MASS GRAMS	44.786
MASS OF FUEL BURNED GRAMS	567.69
MEASURED DISTANCE KM (MILES)	3.321 (2.064)
FUEL CONSUMPTION LB/MILE	20.06 (.085)
HC GRAMS/KM (GRAMS/MILE)	.85 (1.37)
CO GRAMS/KM (GRAMS/MILE)	.05 (.09)
CO2 GRAMS/KM (GRAMS/MILE)	472.2 (759.8)
NOX GRAMS/KM (GRAMS/MILE)	13.48 (21.70)

PARTICULATE RATE
GRAMS/TEST = .000
GRAMS/KG FUEL = .00
GRAMS/KM = .00
GRAMS/MILE = .00
FILTER EFF. = 100.00

CBD VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. CBD-8 RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/14/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80
BAROMETER 740.26 MM HG(29.14 IN HG)	DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)	
RELATIVE HUMIDITY 75. PCT	ABS. HUMIDITY 15.9 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.2

BAG RESULTS

TEST CYCLE	CBD
RUN TIME SECONDS	557.6
TOT. BLOWER RATE SCMM (SCFM)	61.29 (2164.2)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	569.6 (20113.)
HC SAMPLE METER/RANGE/PPM	11.1/ 2/ 11.09
HC BCKGRD METER/RANGE/PPM	3.9/ 2/ 3.90
CO SAMPLE METER/RANGE/PPM	.9/ 12/ 1.22
CO BCKGRD METER/RANGE/PPM	.6/ 12/ .81
CO2 SAMPLE METER/RANGE/PCT	56.7/ 13/.1825
CO2 BCKGRD METER/RANGE/PCT	16.5/ 13/.0368
NOX SAMPLE METER/RANGE/PPM	31.7/ 2/31.81
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	52.86
HC CONCENTRATION PPM	7.27
CO CONCENTRATION PPM	.40
CO2 CONCENTRATION PCT	.1464
NOX CONCENTRATION PPM	31.71
HC MASS GRAMS	2.723
CO MASS GRAMS	.265
CO2 MASS GRAMS	1526.76
NOX MASS GRAMS	41.733
MASS OF FUEL BURNED GRAMS	552.60
MEASURED DISTANCE KM (MILES)	3.361 (2.089)
FUEL CONSUMPTION LB/MILE	19.29 (.082)
HC GRAMS/KM (GRAMS/MILE)	.81 (1.30)
CO GRAMS/KM (GRAMS/MILE)	.08 (.13)
CO2 GRAMS/KM (GRAMS/MILE)	454.2 (730.8)
NOX GRAMS/KM (GRAMS/MILE)	12.42 (19.98)

PARTICULATE RATE
GRAMS/TEST = .000
GRAMS/KG FUEL = .00
GRAMS/KM = .00
GRAMS/MILE = .00
FILTER EFF. = 100.00

CBD VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. CBD-9 RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/14/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80
BAROMETER 740.28 MM HG(29.15 IN HG)	DRY BULB TEMP. 26.1 DEG C(79.0 DEG F)	
RELATIVE HUMIDITY 70. PCT	ABS. HUMIDITY 15.4 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.18

BAG RESULTS

TEST CYCLE	CBD
RUN TIME SECONDS	558.6
TOT. BLOWER RATE SCMM (SCFM)	61.31 (2164.9)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	570.8 (20155.)
HC SAMPLE METER/RANGE/PPM	11.0/ 2/ 10.99
HC BCKGRD METER/RANGE/PPM	3.9/ 2/ 3.90
CO SAMPLE METER/RANGE/PPM	1.1/ 12/ 1.48
CO BCKGRD METER/RANGE/PPM	.8/ 12/ 1.08
CO2 SAMPLE METER/RANGE/PCT	57.3/ 13/.1854
CO2 BCKGRD METER/RANGE/PCT	16.7/ 13/.0373
NOX SAMPLE METER/RANGE/PPM	31.6/ 2/31.71
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	52.02
HC CONCENTRATION PPM	7.17
CO CONCENTRATION PPM	.40
CO2 CONCENTRATION PCT	.1489
NOX CONCENTRATION PPM	31.61
HC MASS GRAMS	2.692
CO MASS GRAMS	.267
CO2 MASS GRAMS	1555.73
NOX MASS GRAMS	40.795
MASS OF FUEL BURNED GRAMS	563.00
MEASURED DISTANCE KM (MILES)	3.331 (2.070)
FUEL CONSUMPTION LB/MILE	19.84 (.084)
HC GRAMS/KM (GRAMS/MILE)	.81 (1.30)
CO GRAMS/KM (GRAMS/MILE)	.08 (.13)
CO2 GRAMS/KM (GRAMS/MILE)	467.0 (751.5)
NOX GRAMS/KM (GRAMS/MILE)	12.25 (19.70)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

APPENDIX C:

Hybrid Bus Test Results Over HDCC

Test Date = 8/13/97 = With Closed-Loop IMPCO & new catalyst

HDCC Test No.	CNG Fuel grams	Cycle miles	Test Dur. sec.	THC g/mi	NMHC g/mi	CO g/mi	NOx g/mi	PM g/mi	CO2 g/mi	BTU/mi
1	0	5.67	1,049	0	0.00	0	0	0	0	0
2	429	5.67	1,049	0.52	0.11	0.09	4.9	0	209	3,311
3	1,089	5.68	1,049	0.88	0.17	0.12	16.2	0	529.5	8,368
4	1,081	5.69	1,047	0.82	0.09	0.17	16.2	0	525.1	8,296
5	1,118	5.69	1,050	0.72	0.08	0.20	15.7	0	543.1	8,576
6	1,125	5.69	1,053	0.68	0.10	0.20	15.6	0	546.4	8,626

Updated 11/20/97 sgf

LHV = 19850 BTU/lb

HDCC VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. HDCC-2 RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/13/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80

BAROMETER 742.52 MM HG(29.23 IN HG)	DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)	
RELATIVE HUMIDITY 80. PCT	ABS. HUMIDITY 16.9 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.25

BAG RESULTS

TEST CYCLE	HDCC
RUN TIME SECONDS	~~672.4~~ → 1049
TOT. BLOWER RATE SCMM (SCFM)	61.61 (2175.3)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	690.4 (24378.)
HC SAMPLE METER/RANGE/PPM	10.5/ 2/ 10.49
HC BCKGRD METER/RANGE/PPM	4.1/ 2/ 4.10
CO SAMPLE METER/RANGE/PPM	.5/ 12/ .68
CO BCKGRD METER/RANGE/PPM	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	45.1/ 13/.1304
CO2 BCKGRD METER/RANGE/PCT	16.7/ 13/.0373
NOX SAMPLE METER/RANGE/PPM	67.3/ 1/16.83
NOX BCKGRD METER/RANGE/PPM	.5/ 1/ .13
DILUTION FACTOR	73.82
HC CONCENTRATION PPM	6.45
CO CONCENTRATION PPM	.66
CO2 CONCENTRATION PCT	.0937
NOX CONCENTRATION PPM	16.71
HC MASS GRAMS	2.929
CO MASS GRAMS	.530
CO2 MASS GRAMS	1183.76
NOX MASS GRAMS	27.667
MASS OF FUEL BURNED GRAMS	429.46
MEASURED DISTANCE KM (MILES)	9.115 (5.665)
FUEL CONSUMPTION LB/MILE	5.53 (.024)
HC GRAMS/KM (GRAMS/MILE)	.32 (.52)
CO GRAMS/KM (GRAMS/MILE)	.06 (.09)
CO2 GRAMS/KM (GRAMS/MILE)	129.9 (209.0)
NOX GRAMS/KM (GRAMS/MILE)	3.04 (4.88)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

HDCC VEHICLE EMISSIONS RESULTS

PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. HDCC-3 RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/13/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80

BAROMETER 742.57 MM HG(29.24 IN HG)	DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)	
RELATIVE HUMIDITY 80. PCT	ABS. HUMIDITY 16.9 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.25

BAG RESULTS

TEST CYCLE	HDCC
RUN TIME SECONDS	1049.1
TOT. BLOWER RATE SCMM (SCFM)	61.51 (2171.9)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	1075.5 (37976.)
HC SAMPLE METER/RANGE/PPM	11.3/ 2/ 11.29
HC BCKGRD METER/RANGE/PPM	4.3/ 2/ 4.30
CO SAMPLE METER/RANGE/PPM	.5/ 12/ .68
CO BCKGRD METER/RANGE/PPM	.1/ 12/ .14
CO2 SAMPLE METER/RANGE/PCT	58.3/ 13/.1904
CO2 BCKGRD METER/RANGE/PCT	17.1/ 13/.0383
NOX SAMPLE METER/RANGE/PPM	35.8/ 2/35.93
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30
DILUTION FACTOR	50.68
HC CONCENTRATION PPM	7.08
CO CONCENTRATION PPM	.53
CO2 CONCENTRATION PCT	.1529
NOX CONCENTRATION PPM	35.63
HC MASS GRAMS	5.008
CO MASS GRAMS	.660
CO2 MASS GRAMS	3010.02
NOX MASS GRAMS	91.904
MASS OF FUEL BURNED GRAMS	1089.17
MEASURED DISTANCE KM (MILES)	9.146 (5.684)
FUEL CONSUMPTION LB/MILE	13.98 (.059)
HC GRAMS/KM (GRAMS/MILE)	.55 (.88)
CO GRAMS/KM (GRAMS/MILE)	.07 (.12)
CO2 GRAMS/KM (GRAMS/MILE)	329.1 (529.5)
NOX GRAMS/KM (GRAMS/MILE)	10.05 (16.17)

PARTICULATE RATE

GRAMS/TEST = .000

GRAMS/KG FUEL = .00

GRAMS/KM = .00

GRAMS/MILE = .00

FILTER EFF. = 100.00

HDCC VEHICLE EMISSIONS RESULTS

PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. HDCC-4 RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/13/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80

BAROMETER 742.47 MM HG(29.23 IN HG)	DRY BULB TEMP. 24.4 DEG C(76.0 DEG F)	
RELATIVE HUMIDITY 83. PCT	ABS. HUMIDITY 16.5 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.23

BAG RESULTS

TEST CYCLE	HDCC
RUN TIME SECONDS	1047.0
TOT. BLOWER RATE SCMM (SCFM)	61.38 (2167.3)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	1071.1 (37820.)
HC SAMPLE METER/RANGE/PPM	11.9/ 2/ 11.89
HC BCKGRD METER/RANGE/PPM	5.4/ 2/ 5.40
CO SAMPLE METER/RANGE/PPM	.6/ 12/ .81
CO BCKGRD METER/RANGE/PPM	.0/ 12/ .00
CO2 SAMPLE METER/RANGE/PCT	58.2/ 13/.1899
CO2 BCKGRD METER/RANGE/PCT	17.1/ 13/.0383
NOX SAMPLE METER/RANGE/PPM	36.5/ 2/36.63
NOX BCKGRD METER/RANGE/PPM	.2/ 2/ .20
DILUTION FACTOR	50.79
HC CONCENTRATION PPM	6.60
CO CONCENTRATION PPM	.79
CO2 CONCENTRATION PCT	.1524
NOX CONCENTRATION PPM	36.43
HC MASS GRAMS	4.650
CO MASS GRAMS	.982
CO2 MASS GRAMS	2987.75
NOX MASS GRAMS	92.046
MASS OF FUEL BURNED GRAMS	1080.98
MEASURED DISTANCE KM (MILES)	9.155 (5.690)
FUEL CONSUMPTION LB/MILE	13.86 (.059)
HC GRAMS/KM (GRAMS/MILE)	.51 (.82)
CO GRAMS/KM (GRAMS/MILE)	.11 (.17)
CO2 GRAMS/KM (GRAMS/MILE)	326.3 (525.1)
NOX GRAMS/KM (GRAMS/MILE)	10.05 (16.18)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

HDCC VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325

PROGRAM = SOR09S

TEST NO. HDCC-5 RUN 1
VEHICLE MODEL 97 ALLISON HY
ENGINE 2.0 L(122. CID)
TRANSMISSION NA
GVW = 6124. KG (13500. LBS)

VEHICLE NO.
DATE 8/13/97
BAG CART NO. 2
DYNO NO. 4
CVS NO. 11

TEST WEIGHT 6623. KG(14600. LBS)
ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
CNG-SI CNG
ODOMETER 0. KM(0. MILES)
HCR = 3.80

BAROMETER 741.78 MM HG(29.20 IN HG)
RELATIVE HUMIDITY 76. PCT

DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)
ABS. HUMIDITY 16.2 GM/KG

NOX HUMIDITY CORRECTION FACTOR 1.22

BAG RESULTS

TEST CYCLE	HDCC
RUN TIME SECONDS	1049.7
TOT. BLOWER RATE SCMM (SCFM)	61.31 (2165.0)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	1072.7 (37876.)
HC SAMPLE METER/RANGE/PPM	12.0/ 2/ 11.99
HC BCKGRD METER/RANGE/PPM	6.3/ 2/ 6.30
CO SAMPLE METER/RANGE/PPM	.9/ 12/ 1.22
CO BCKGRD METER/RANGE/PPM	.2/ 12/ .27
CO2 SAMPLE METER/RANGE/PCT	59.2/ 13/.1950
CO2 BCKGRD METER/RANGE/PCT	17.1/ 13/.0383
NOX SAMPLE METER/RANGE/PPM	35.7/ 2/35.83
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	49.47
HC CONCENTRATION PPM	5.82
CO CONCENTRATION PPM	.92
CO2 CONCENTRATION PCT	.1574
NOX CONCENTRATION PPM	35.73
HC MASS GRAMS	4.108
CO MASS GRAMS	1.146
CO2 MASS GRAMS	3091.91
NOX MASS GRAMS	89.418
MASS OF FUEL BURNED GRAMS	1118.04
MEASURED DISTANCE KM (MILES)	9.161 (5.693)
FUEL CONSUMPTION LB/MILE	14.32 (.061)
HC GRAMS/KM (GRAMS/MILE)	.45 (.72)
CO GRAMS/KM (GRAMS/MILE)	.13 (.20)
CO2 GRAMS/KM (GRAMS/MILE)	337.5 (543.1)
NOX GRAMS/KM (GRAMS/MILE)	9.76 (15.71)

PARTICULATE RATE
GRAMS/TEST = .000
GRAMS/KG FUEL = .00
GRAMS/KM = .00
GRAMS/MILE = .00
FILTER EFF. = 100.00

HDCC VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. HDCC-6 RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/13/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80

BAROMETER 741.78 MM HG(29.20 IN HG)	DRY BULB TEMP. 25.6 DEG C(78.0 DEG F)	
RELATIVE HUMIDITY 73. PCT	ABS. HUMIDITY 15.4 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.1

BAG RESULTS

TEST CYCLE	HDCC
RUN TIME SECONDS	1052.7
TOT. BLOWER RATE SCMM (SCFM)	61.32 (2165.3)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	1075.9 (37990.)
HC SAMPLE METER/RANGE/PPM	10.6/ 2/ 10.59
HC BCKGRD METER/RANGE/PPM	5.2/ 2/ 5.20
CO SAMPLE METER/RANGE/PPM	1.2/ 12/ 1.61
CO BCKGRD METER/RANGE/PPM	.5/ 12/ .68
CO2 SAMPLE METER/RANGE/PCT	59.1/ 13/.1945
CO2 BCKGRD METER/RANGE/PCT	16.7/ 13/.0373
NOX SAMPLE METER/RANGE/PPM	34.1/ 2/34.22
NOX BCKGRD METER/RANGE/PPM	.1/ 2/ .10
DILUTION FACTOR	49.62
HC CONCENTRATION PPM	5.50
CO CONCENTRATION PPM	.92
CO2 CONCENTRATION PCT	.1579
NOX CONCENTRATION PPM	34.12
HC MASS GRAMS	3.892
CO MASS GRAMS	1.148
CO2 MASS GRAMS	3111.05
NOX MASS GRAMS	82.893
MASS OF FUEL BURNED GRAMS	1124.71
MEASURED DISTANCE KM (MILES)	9.162 (5.694)
FUEL CONSUMPTION LB/MILE	14.41 (.061)
HC GRAMS/KM (GRAMS/MILE)	.42 (.68)
CO GRAMS/KM (GRAMS/MILE)	.13 (.20)
CO2 GRAMS/KM (GRAMS/MILE)	339.6 (546.4)
NOX GRAMS/KM (GRAMS/MILE)	9.05 (14.56)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

APPENDIX D:

Steady-State Hybrid Bus APU Test Results

As Receiv
SwRI Mod

Load, kW	After Mods time sec	Fuel g	THC g	NMHC g	CO g	NOx g	CO2 g
4	420.0	194.8	1.5	0.04	10.0	0.1	521
7.5	420.1	250.0	2.2	0.22	11.9	0.1	670
11	419.9	309.0	2.7	0.17	6.9	2.2	840
14	420.8	377.8	0.7	0.11	0.1	22.7	1,047
17.5	420.0	504.5	0.5	0.23	0.2	36.1	1,399
23	420.0	662.0	4.2	2.61	0.3	66.9	1,827

Load, kW	est flywheel hp	THC (g/hr)	NMHC (g/hr)	CO (g/hr)	NOx (g/hr)	NOx (g/hr)	Fuel (BTU/hr)
4	6.3	13.3	0.36	85.7	0.6	4,465	72,898
7.5	11.8	18.6	1.87	101.9	0.6	5,739	93,538
11	17.4	23.4	1.46	59.5	19.2	7,196	115,676
14	22.1	5.6	0.96	0.6	194.2	8,976	141,132
17.5	27.6	4.4	1.96	1.7	309.8	11,994	188,834
23	36.3	35.9	22.38	2.3	573.4	15,656	247,792

LHV = 19850 BTU/lb

Load, kW	bsfc (lb/hp-hr)	THC (g/hp-hr)	NMHC (g/hp-hr)	CO (g/hp-hr)	NOx (g/hp-hr)	NOx (g/hp-hr)
4	0.58	2.1	0.06	13.6	0.1	707.5
7.5	0.40	1.6	0.16	8.6	0.0	485.0
11	0.34	1.3	0.08	3.4	1.1	414.7
14	0.32	0.3	0.04	0.0	8.8	406.4
17.5	0.34	0.2	0.07	0.1	11.2	434.4
23	0.34	1.0	0.62	0.1	15.8	431.5

SS APU Tests

TEST NO. 55-30K RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/ 8/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80

BAROMETER 740.94 MM HG(29.17 IN HG)	DRY BULB TEMP. 22.8 DEG C(73.0 DEG F)	
RELATIVE HUMIDITY 57. PCT	ABS. HUMIDITY 10.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR .98

BAG RESULTS

TEST CYCLE	55-30
RUN TIME SECONDS	420.0
TOT. BLOWER RATE SCMM (SCFM)	61.35 (2166.3)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	429.5 (15164.)
HC SAMPLE METER/RANGE/PPM	19.6/ 2/ 19.59
HC BCKGRD METER/RANGE/PPM	4.9/ 2/ 4.90
CO SAMPLE METER/RANGE/PPM	.8/ 12/ 1.08
CO BCKGRD METER/RANGE/PPM	.4/ 12/ .54
CO2 SAMPLE METER/RANGE/PCT	72.8/ 13/.2721
CO2 BCKGRD METER/RANGE/PCT	18.1/ 13/.0409
NOX SAMPLE METER/RANGE/PPM	82.9/ 2/83.19
NOX BCKGRD METER/RANGE/PPM	.3/ 2/ .30
DILUTION FACTOR	35.42
HC CONCENTRATION PPM	14.83
CO CONCENTRATION PPM	.53
CO2 CONCENTRATION PCT	.2323
NOX CONCENTRATION PPM	82.90
HC MASS GRAMS	4.188
CO MASS GRAMS	.267
CO2 MASS GRAMS	1826.51
NOX MASS GRAMS	66.902
MASS OF FUEL BURNED GRAMS	661.99
MEASURED DISTANCE KM (MILES)	.001 (.000)
FUEL CONSUMPTION LB/MILE	****** (******)
HC GRAMS/KM (GRAMS/MILE)	****** (******)
CO GRAMS/KM (GRAMS/MILE)	388.12 (624.48)
CO2 GRAMS/KM (GRAMS/MILE)	****** (******)
NOX GRAMS/KM (GRAMS/MILE)	***** (******)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

55-25 VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. 55-25K RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/ 8/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80
BAROMETER 740.99 MM HG(29.17 IN HG)	DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)	
RELATIVE HUMIDITY 64. PCT	ABS. HUMIDITY 12.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.05

BAG RESULTS

TEST CYCLE	55-25
RUN TIME SECONDS	420.0
TOT. BLOWER RATE SCMM (SCFM)	61.33 (2165.7)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	429.3 (15160.)
HC SAMPLE METER/RANGE/PPM	67.0/ 1/ 6.72
HC BCKGRD METER/RANGE/PPM	49.8/ 1/ 5.00
CO SAMPLE METER/RANGE/PPM	.9/ 12/ 1.22
CO BCKGRD METER/RANGE/PPM	.6/ 12/ .81
CO2 SAMPLE METER/RANGE/PCT	63.9/ 13/.2198
CO2 BCKGRD METER/RANGE/PCT	18.8/ 13/.0428
NOX SAMPLE METER/RANGE/PPM	42.6/ 2/42.75
NOX BCKGRD METER/RANGE/PPM	.9/ 2/ .90
DILUTION FACTOR	44.02
HC CONCENTRATION PPM	1.84
CO CONCENTRATION PPM	.40
CO2 CONCENTRATION PCT	.1780
NOX CONCENTRATION PPM	41.87
HC MASS GRAMS	.519
CO MASS GRAMS	.202
CO2 MASS GRAMS	1399.33
NOX MASS GRAMS	36.148
MASS OF FUEL BURNED GRAMS	504.48
MEASURED DISTANCE KM (MILES)	.001 (.000)
FUEL CONSUMPTION LB/MILE	****** (******)
HC GRAMS/KM (GRAMS/MILE)	754.63 (******)
CO GRAMS/KM (GRAMS/MILE)	293.06 (471.53)
CO2 GRAMS/KM (GRAMS/MILE)	****** (******)
NOX GRAMS/KM (GRAMS/MILE)	***** (******)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

55-20 VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325

PROGRAM = SOR09S

TEST NO. 55-20K RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/ 8/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80
BAROMETER 740.99 MM HG(29.17 IN HG)	DRY BULB TEMP. 23.9 DEG C(75.0 DEG F)	
RELATIVE HUMIDITY 64. PCT	ABS. HUMIDITY 12.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.05

BAG RESULTS

TEST CYCLE	55-20
RUN TIME SECONDS	420.8
TOT. BLOWER RATE SCMM (SCFM)	61.51 (2171.9)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	431.4 (15233.)
HC SAMPLE METER/RANGE/PPM	68.3/ 1/ 6.85
HC BCKGRD METER/RANGE/PPM	46.2/ 1/ 4.64
CO SAMPLE METER/RANGE/PPM	.8/ 12/ 1.08
CO BCKGRD METER/RANGE/PPM	.7/ 12/ .95
CO2 SAMPLE METER/RANGE/PCT	55.4/ 13/.1762
CO2 BCKGRD METER/RANGE/PCT	19.4/ 13/.0444
NOX SAMPLE METER/RANGE/PPM	27.0/ 2/27.10
NOX BCKGRD METER/RANGE/PPM	1.0/ 2/ 1.00
DILUTION FACTOR	54.88
HC CONCENTRATION PPM	2.30
CO CONCENTRATION PPM	.14
CO2 CONCENTRATION PCT	.1326
NOX CONCENTRATION PPM	26.11
HC MASS GRAMS	.653
CO MASS GRAMS	.072
CO2 MASS GRAMS	1047.23
NOX MASS GRAMS	22.651
MASS OF FUEL BURNED GRAMS	377.76
MEASURED DISTANCE KM (MILES)	.001 (.000)
FUEL CONSUMPTION LB/MILE	****** (******)
HC GRAMS/KM (GRAMS/MILE)	948.97 (******)
CO GRAMS/KM (GRAMS/MILE)	103.95 (167.25)
CO2 GRAMS/KM (GRAMS/MILE)	****** (******)
NOX GRAMS/KM (GRAMS/MILE)	***** (******)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

55-15 VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. 55-15K RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/ 8/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80
BAROMETER 741.02 MM HG(29.17 IN HG)	DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)	
RELATIVE HUMIDITY 76. PCT	ABS. HUMIDITY 14.1 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.12

BAG RESULTS

TEST CYCLE	55-15
RUN TIME SECONDS	419.9
TOT. BLOWER RATE SCMM (SCFM)	61.36 (2166.5)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	429.4 (15162.)
HC SAMPLE METER/RANGE/PPM	15.0/ 2/ 14.99
HC BCKGRD METER/RANGE/PPM	5.4/ 2/ 5.40
CO SAMPLE METER/RANGE/PPM	13.6/ 12/ 15.89
CO BCKGRD METER/RANGE/PPM	1.2/ 12/ 1.61
CO2 SAMPLE METER/RANGE/PCT	49.7/ 13/.1499
CO2 BCKGRD METER/RANGE/PCT	19.2/ 13/.0438
NOX SAMPLE METER/RANGE/PPM	3.0/ 2/ 3.01
NOX BCKGRD METER/RANGE/PPM	2.4/ 1/ .60
DILUTION FACTOR	63.47
HC CONCENTRATION PPM	9.68
CO CONCENTRATION PPM	13.89
CO2 CONCENTRATION PCT	.1068
NOX CONCENTRATION PPM	2.42
HC MASS GRAMS	2.733
CO MASS GRAMS	6.941
CO2 MASS GRAMS	839.57
NOX MASS GRAMS	2.235
MASS OF FUEL BURNED GRAMS	308.96
MEASURED DISTANCE KM (MILES)	.001 (.000)
FUEL CONSUMPTION LB/MILE	****** (******)
HC GRAMS/KM (GRAMS/MILE)	****** (******)
CO GRAMS/KM (GRAMS/MILE)	****** (******)
CO2 GRAMS/KM (GRAMS/MILE)	****** (******)
NOX GRAMS/KM (GRAMS/MILE)	***** (******)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

55-10 VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325 PROGRAM = SOR09S

TEST NO. 55-10K RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/ 8/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80

BAROMETER 740.99 MM HG(29.17 IN HG)	DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)	
RELATIVE HUMIDITY 66. PCT	ABS. HUMIDITY 12.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.05

BAG RESULTS

TEST CYCLE	55-10
RUN TIME SECONDS	420.1
TOT. BLOWER RATE SCMM (SCFM)	61.44 (2169.5)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	430.2 (15190.)
HC SAMPLE METER/RANGE/PPM	12.6/ 2/ 12.59
HC BCKGRD METER/RANGE/PPM	5.0/ 2/ 5.00
CO SAMPLE METER/RANGE/PPM	25.3/ 12/ 27.35
CO BCKGRD METER/RANGE/PPM	2.3/ 12/ 3.04
CO2 SAMPLE METER/RANGE/PCT	44.5/ 13/.1280
CO2 BCKGRD METER/RANGE/PCT	19.1/ 13/.0436
NOX SAMPLE METER/RANGE/PPM	1.4/ 1/ .35
NOX BCKGRD METER/RANGE/PPM	1.1/ 1/ .28
DILUTION FACTOR	73.62
HC CONCENTRATION PPM	7.66
CO CONCENTRATION PPM	23.73
CO2 CONCENTRATION PCT	.0850
NOX CONCENTRATION PPM	.08
HC MASS GRAMS	2.168
CO MASS GRAMS	11.883
CO2 MASS GRAMS	669.50
NOX MASS GRAMS	.068
MASS OF FUEL BURNED GRAMS	249.95
MEASURED DISTANCE KM (MILES)	.001 (.000)
FUEL CONSUMPTION LB/MILE	****** (******)
HC GRAMS/KM (GRAMS/MILE)	****** (******)
CO GRAMS/KM (GRAMS/MILE)	****** (******)
CO2 GRAMS/KM (GRAMS/MILE)	****** (******)
NOX GRAMS/KM (GRAMS/MILE)	99.03 (159.35)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

55-5 VEHICLE EMISSIONS RESULTS
PROJECT 02-5137-325

PROGRAM = SOR09S

TEST NO. 55-5KW RUN 1	VEHICLE NO.	TEST WEIGHT 6623. KG(14600. LBS)
VEHICLE MODEL 97 ALLISON HY	DATE 8/ 8/97	ACTUAL ROAD LOAD 38.9 KW(52.2 HP)
ENGINE 2.0 L(122. CID)	BAG CART NO. 2	CNG-SI CNG
TRANSMISSION NA	DYNO NO. 4	ODOMETER 0. KM(0. MILES)
GVW = 6124. KG (13500. LBS)	CVS NO. 11	HCR = 3.80

BAROMETER 740.99 MM HG(29.17 IN HG)	DRY BULB TEMP. 23.3 DEG C(74.0 DEG F)	
RELATIVE HUMIDITY 66. PCT	ABS. HUMIDITY 12.2 GM/KG	NOX HUMIDITY CORRECTION FACTOR 1.05

BAG RESULTS

TEST CYCLE	55-5
RUN TIME SECONDS	420.0
TOT. BLOWER RATE SCMM (SCFM)	61.57 (2174.2)
TOT. 20X20 RATE SCMM (SCFM)	.00 (.0)
TOT. AUX. SAMPLE RATE SCMM (SCFM)	.00 (.00)
TOT FLOW STD. CU. METRES(SCF)	431.0 (15219.)
HC SAMPLE METER/RANGE/PPM	10.8/ 2/ 10.79
HC BCKGRD METER/RANGE/PPM	5.4/ 2/ 5.40
CO SAMPLE METER/RANGE/PPM	20.8/ 12/ 23.06
CO BCKGRD METER/RANGE/PPM	2.0/ 12/ 2.66
CO2 SAMPLE METER/RANGE/PCT	39.3/ 13/.1078
CO2 BCKGRD METER/RANGE/PCT	18.6/ 13/.0422
NOX SAMPLE METER/RANGE/PPM	.9/ 1/ .23
NOX BCKGRD METER/RANGE/PPM	.6/ 1/ .15
DILUTION FACTOR	87.41
HC CONCENTRATION PPM	5.46
CO CONCENTRATION PPM	19.92
CO2 CONCENTRATION PCT	.0660
NOX CONCENTRATION PPM	.08
HC MASS GRAMS	1.547
CO MASS GRAMS	9.997
CO2 MASS GRAMS	520.87
NOX MASS GRAMS	.067
MASS OF FUEL BURNED GRAMS	194.75
MEASURED DISTANCE KM (MILES)	.001 (.000)
FUEL CONSUMPTION LB/MILE	****** (******)
HC GRAMS/KM (GRAMS/MILE)	****** (******)
CO GRAMS/KM (GRAMS/MILE)	****** (******)
CO2 GRAMS/KM (GRAMS/MILE)	****** (******)
NOX GRAMS/KM (GRAMS/MILE)	96.68 (155.56)

PARTICULATE RATE

GRAMS/TEST =	.000
GRAMS/KG FUEL =	.00
GRAMS/KM =	.00
GRAMS/MILE =	.00
FILTER EFF. =	100.00

Fuels Distribution List

Department of Defense

DEFENSE TECH INFO CTR 12
ATTN: DTIC OCC
8725 JOHN J KINGMAN RD
STE 0944
FT BELVOIR VA 22060-6218

ODUSD
ATTN: (L) MRM 1
PETROLEUM STAFF ANALYST
PENTAGON
WASHINGTON DC 20301-8000

US CINCPAC
ATTN: J422 BOX 64020 1
CAMP H M SMITH
HI 96861-4020

JOAP TSC 1
BLDG 780
NAVAL AIR STA
PENSACOLA FL 32508-5300

DIR DLA
ATTN: DLA MMSLP 1
8725 JOHN J KINGMAN RD
STE 2533
FT BELVOIR VA 22060-6221

CDR
DEFENSE FUEL SUPPLY CTR
ATTN: DFSC I (C MARTIN) 1
DFSC IT (R GRAY) 1
DFSC IQ (L OPPENHEIM) 1
8725 JOHN J KINGMAN RD
STE 2941
FT BELVOIR VA 22060-6222

DIR
DEFENSE ADV RSCH PROJ AGENCY
ATTN: ARPA/ASTO 1
3701 N FAIRFAX DR
ARLINGTON VA 22203-1714

Department of the Army

HQDA
ATTN: DALO TSE 1
DALO SM 1
500 PENTAGON
WASHINGTON DC 20310-0500

SARDA
ATTN: SARD TT 1
PENTAGON
WASHINGTON DC 20310-0103

CDR AMC
ATTN: AMCRD S 1
AMCRD E 1
AMCRD IT 1
AMCEN A 1
AMCLG M 1
AMXLS H 1
5001 EISENHOWER AVE
ALEXANDRIA VA 22333-0001

U.S. ARMY TACOM
TARDEC PETR. & WTR. BUS. AREA
ATTN AMSTA TR-D/210 (L. VILLHAHERMOSA)10
AMSTA TR-D/210 (T. BAGWELL) 1
WARREN, MI 48397-5000

CDR ARMY TACOM
ATTN: AMSTA IM LMM 1
AMSTA IM LMB 1
AMSTA IM LMT 1
AMSTA TR NAC MS 002 1
AMSTA TR R MS 202 1
AMSTA TR D MS 201A 1
AMSTA TR M 1
AMSTA TR R MS 121 (C RAFFA) 1
AMSTA TR R MS 158 (D HERRERA) 1
AMSTA TR R MS 121 (R MUNT) 1
AMCPM ATP MS 271 1
AMSTA TR E MS 203 1
AMSTA TR K 1
AMSTA IM KP 1
AMSTA IM MM 1
AMSTA IM MT 1
AMSTA IM MC 1
AMSTA IM GTL 1
AMSTA CL NG 1
USMC LNO 1
AMCPM LAV 1
AMCPM M113 1
AMCPM CCE 1
WARREN MI 48397-5000

Department of the Army

PROG EXEC OFFICER
ARMORED SYS MODERNIZATION
ATTN: SFAE ASM S 1
SFAE ASM H 1
SFAE ASM AB 1
SFAE ASM BV 1
SFAE ASM CV 1
SFAE ASM AG 1
CDR TACOM
WARREN MI 48397-5000

PROG EXEC OFFICER
ARMORED SYS MODERNIZATION
ATTN: SFAE FAS AL 1
SFAE FAS PAL 1
PICATINNY ARSENAL
NJ 07806-5000

PROG EXEC OFFICER
TACTICAL WHEELED VEHICLES
ATTN: SFAE TWV TVSP 1
SFAE TWV FMTV 1
SFAE TWV PLS 1
CDR TACOM
WARREN MI 48397-5000

PROG EXEC OFFICER
ARMAMENTS
ATTN: SFAE AR HIP 1
SFAE AR TMA 1
PICATINNY ARSENAL
NJ 07806-5000

PROG MGR
UNMANNED GROUND VEH
ATTN: AMCPM UG 1
REDSTONE ARSENAL
AL 35898-8060

DIR
ARMY RSCH LAB
ATTN: AMSRL PB P 1
2800 POWDER MILL RD
ADELPHIA MD 20783-1145

VEHICLE PROPULSION DIR
ATTN: AMSRL VP (MS 77 12) 1
NASA LEWIS RSCH CTR
21000 BROOKPARK RD
CLEVELAND OH 44135

CDR AMSAA
ATTN: AMXSY CM 1
AMXSY L 1
APG MD 21005-5071

CDR ARO
ATTN: AMXRO EN (D MANN) 1
RSCH TRIANGLE PK
NC 27709-2211

CDR AEC
ATTN: SFIM AEC ECC (T ECCLES) 1
APG MD 21010-5401

CDR ARMY SOLDIER SPT CMD
ATTN: SATNC US (J SIEGEL) 1
SATNC UE 1
NATICK MA 01760-5018

CDR ARMY ARDEC
ATTN: AMSTA AR EDE S 1
PICATINNY ARSENAL
NJ 07808-5000

CDR ARMY WATERVLIET ARSN
ATTN: SARWY RDD 1
WATERVLIET NY 12189

CDR APC
ATTN: SATPC L 1
SATPC Q 1
NEW CUMBERLAND PA 17070-5005

CDR ARMY LEA
ATTN: LOEA PL 1
NEW CUMBERLAND PA 17070-5007

CDR ARMY TECOM
ATTN: AMSTE TA R 1
AMSTE TC D 1
AMSTE EQ 1
APG MD 21005-5006

PROJ MGR MOBILE ELEC PWR
ATTN: AMCPM MEP T 1
AMCPM MEP L 1
7798 CISSNA RD STE 200
SPRINGFIELD VA 22150-3199

CDR
ARMY COLD REGION TEST CTR
ATTN: STECR TM 1
STECR LG 1
APO AP 96508-7850

CDR ARMY ORDN CTR
ATTN: ATSL CD CS 1
APG MD 21005

CDR 49TH QM GROUP
ATTN: AFFL GC 1
FT LEE VA 23801-5119

CDR
ARMY BIOMED RSCH DEV LAB
ATTN: SGRD UBZ A 1
FT DETRICK MD 21702-5010

CDR FORSCOM
ATTN: AFLG TRS 1
FT MCPHERSON GA 30330-6000

CDR ARMY QM SCHOOL
ATTN: ATSM PWD 1
FT LEE VA 23001-5000

CDR TRADOC
ATTN: ATCD SL 5 1
INGALLS RD BLDG 163
FT MONROE VA 23651-5194

CDR ARMY ARMOR CTR
ATTN: ATSB CD ML 1
ATSB TSM T 1
FT KNOX KY 40121-5000

CDR ARMY FIELD ARTY SCH
ATTN: ATSF CD 1
FT SILL OK 73503

CDR ARMY TRANS SCHOOL
ATTN: ATSP CD MS 1
FT EUSTIS VA 23604-5000

CDR ARMY INF SCHOOL
ATTN: ATSH CD 1
ATSH AT 1
FT BENNING GA 31905-5000

CDR ARMY AVIA CTR
ATTN: ATZQ DOL M 1
FT RUCKER AL 36362-5115

CDR ARMY ENGR SCHOOL
ATTN: ATSE CD 1
FT LEONARD WOOD
MO 65473-5000

CDR ARMY ABERDEEN TEST CTR
ATTN: STEAC EN 1
STEAC LI 1
STEAC AE 1
STEAC AA 1
APG MD 21005-5059

CDR ARMY SAFETY CTR
ATTN: CSSC PMG 1
CSSC SPS 1
FT RUCKER AL 36362-5363

CDR ARMY YPG
ATTN: STEYP MT TL M 1
YUMA AZ 85365-9130

CDR ARMY CERL
ATTN: CECER EN 1
P O BOX 9005
CHAMPAIGN IL 61826-9005

DIR 1
AMC FAST PROGRAM
10101 GRIDLEY RD STE 104
FT BELVOIR VA 22060-5818

CDR I CORPS AND FT LEWIS
ATTN: AFZH CSS 1
FT LEWIS WA 98433-5000

CDR
RED RIVER ARMY DEPOT
ATTN: SDSRR M 1
SDSRR Q 1
TEXARKANA TX 75501-5000

PS MAGAZINE DIV
ATTN: AMXLS PS 1
DIR LOGSA
REDSTONE ARSENAL AL 35898-7466

Department of the Navy

OFC CHIEF NAVAL OPER
ATTN: DR A ROBERTS (N420) 1
2000 NAVY PENTAGON
WASHINGTON DC 20350-2000

CDR
NAVAL SEA SYSTEMS CMD
ATTN: SEA 03M3 1
2531 JEFFERSON DAVIS HWY
ARLINGTON VA 22242-5160

CDR

CDR
NAVAL AIR WARFARE CTR
ATTN: CODE PE33 AJD 1
P O BOX 7176
TRENTON NJ 08628-0176

CDR 1
NAVAL PETROLEUM OFFICE
8725 JOHN J KINGMAN RD
STE 3719
FT BELVOIR VA 22060-6224

CDR

NAVAL SURFACE WARFARE CTR
ATTN: CODE 63 1
CODE 632 1
CODE 859 1
3A LEGGETT CIRCLE
ANNAPOLIS MD 21402-5067

NAVAL RSCH LABORATORY
ATTN: CODE 6181 1
WASHINGTON DC 20375-5342

Department of the Navy/U.S. Marine Corps

HQ USMC
ATTN: LPP 1
WASHINGTON DC 20380-0001

PROG MGR COMBAT SER SPT 1
MARINE CORPS SYS CMD
2033 BARNETT AVE STE 315
QUANTICO VA 22134-5080

PROG MGR GROUND WEAPONS 1
MARINE CORPS SYS CMD
2033 BARNETT AVE
QUANTICO VA 22134-5080
PROG MGR ENGR SYS 1
MARINE CORPS SYS CMD
2033 BARNETT AVE
QUANTICO VA 22134-5080

CDR
MARINE CORPS SYS CMD
ATTN: SSE 1
2030 BARNETT AVE STE 315
QUANTICO VA 22134-5010

CDR
BLOUNT ISLAND CMD
ATTN: CODE 922/1 1
5880 CHANNEL VIEW BLVD
JACKSONVILLE FL 32226-3404

CDR
ATTN: CODE 837 1
814 RADFORD BLVD
ALBANY GA 31704-1128

CDR 1
2ND MARINE DIV
PSC BOX 20090
CAMP LEJEUNNE
NC 28542-0090

CDR 1
FMFPAC G4
BOX 64118
CAMP H M SMITH
HI 96861-4118

Department of the Air Force

HQ USAF/LGSF
ATTN: FUELS POLICY 1
1030 AIR FORCE PENTAGON
WASHINGTON DC 20330-1030

HQ USAF/LGTV
ATTN: VEH EQUIP/FACILITY 1
1030 AIR FORCE PENTAGON
WASHINGTON DC 20330-1030

AIR FORCE WRIGHT LAB
ATTN: WL/POS 1
WL/POSF 1
1790 LOOP RD N
WRIGHT PATTERSON AFB
OH 45433-7103

AIR FORCE MEEP MGMT OFC 1
OL ZC AFMC LSO/LOT PM
201 BISCAYNE DR
BLDG 613 STE 2
ENGLIN AFB FL 32542-5303

SA ALC/SFT 1
1014 BILLY MITCHELL BLVD STE 1
KELLY AFB TX 78241-5603

SA ALC/LDPG
ATTN: D ELLIOTT 1
580 PERRIN BLDG 329
KELLY AFB TX 78241-6439

WR ALC/LVRS 1
225 OCMULGEE CT
ROBINS AFB
GA 31098-1647

Other Federal Agencies

NASA
LEWIS RESEARCH CENTER 1
CLEVELAND OH 44135

RAYMOND P. ANDERSON, PH.D., MANAGER 1
FUELS & ENGINE TESTING
BDM-OKLAHOMA, INC.
220 N. VIRGINIA
BARTLESVILLE OK 74003

EPA
AIR POLLUTION CONTROL 1
2565 PLYMOUTH RD
ANN ARBOR MI 48105

DOT
FAA
AWS 110 1
800 INDEPENDENCE AVE SW
WASHINGTON DC 20590